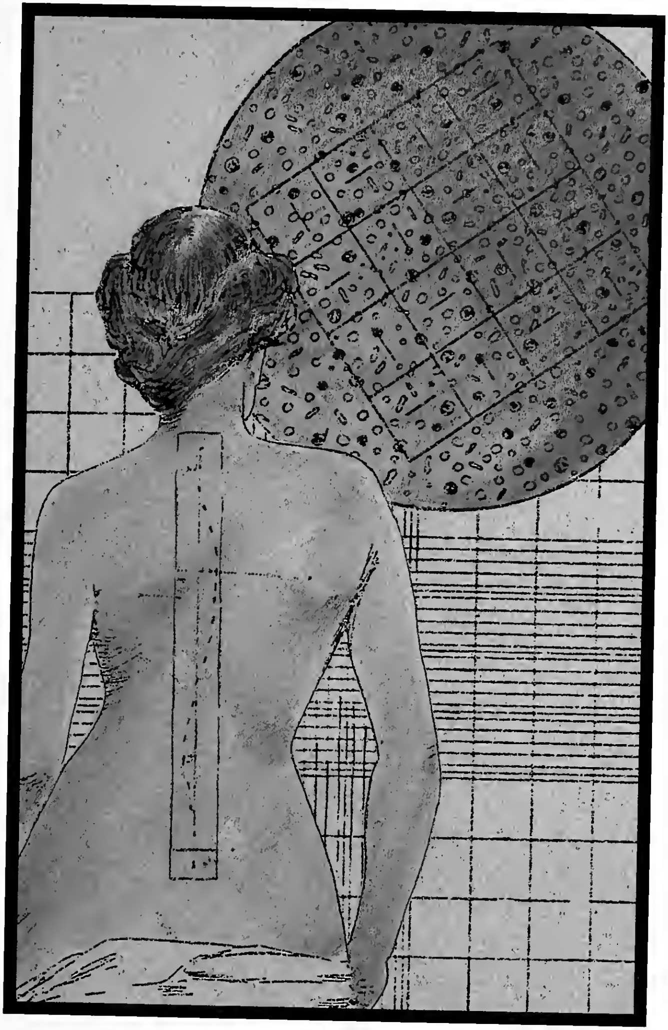

Studies in Anatomy and Technology

C A D U C E U S

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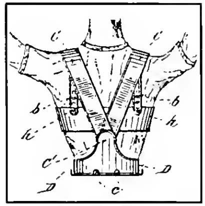

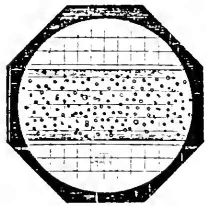

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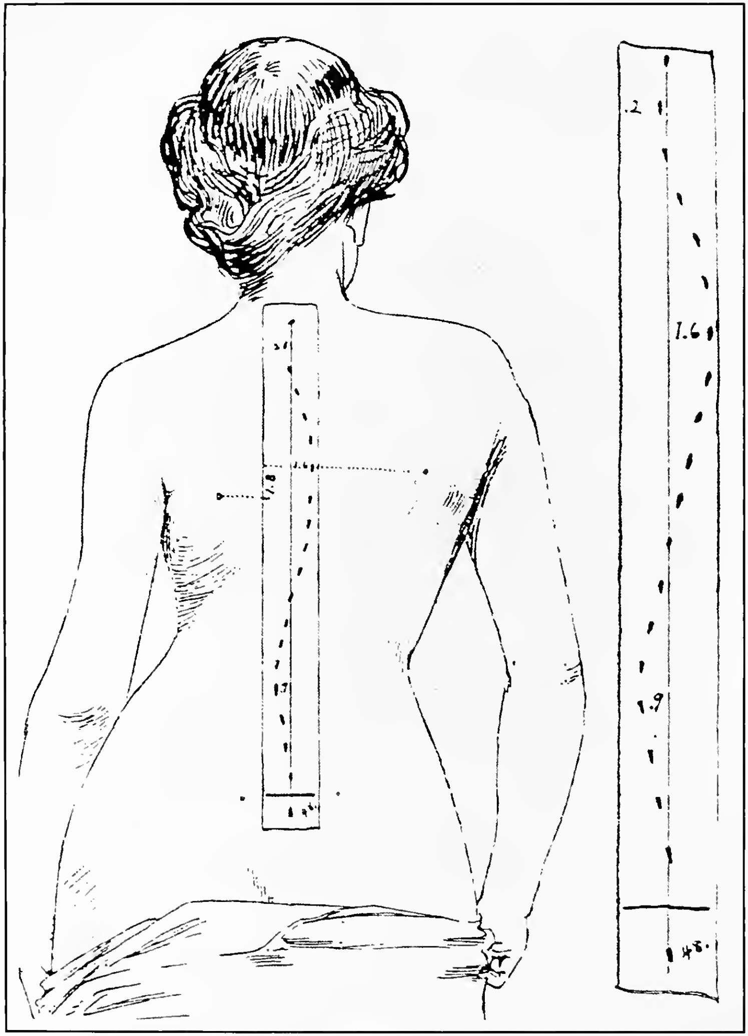


Figure 1. Typical scoliosis curve, right dorsal–left lumbar type.

Medical and Commercial Supports for Scoliotic Patients, 1819–1935

Scoliosis, lateral curvature of the spine (Figure 1), presently affects only two to four percent of the United States population.[1] In the nineteenth and early twentieth centuries, scoliosis seems to have been a pervasive orthopedic malady, causing pain, hindering movement, and creating a social handicap for children and adolescents.[2] Scoliosis was as difficult to treat as it was widespread. General practitioners and specialists, orthodox and sectarian physicians, exercised their powers of analysis and imagination to find a treatment or combination of treatments to remove or reduce the curvature. Each new therapy was hailed as the answer. Each was eventually acknowledged to fall short of a cure.

Many physicians made use of some type of supporting device (orthosis) in their efforts to alleviate a curvature or prevent an incipient case from progressing. Rigid "jackets," similar to body casts, provided either long-term support for the spine or pressure on protruding parts of the torso. Braces made of metal, leather, and textiles provided adjustable pressure and attempted to relieve stresses on the spine. Orthopedic corsets of many materials and designs were used as retainers of postural corrections that had been achieved by exercise or passive manipulation. All such items were medically prescribed. Inventors, entrepreneurs, and instrument-makers also created and marketed an array of nonprescription braces, corsets, suspenders, and even brassieres. They were advertised as devices to correct or mask spinal curvature and also kyphosis, popularly called "round shoulders."

This paper relates the development and use of various supporting devices to the evolving medical understanding of the etiology and mechanism of scoliosis. Each type of device was part of a strategy for offering scoliotics relief from pain, easier movement, and a more socially acceptable appearance. Some types of support remain in use today by orthopedists. Others have been discarded by physicians or, in the case of most commercial devices, by consumers. One class of support, the brassiere, has become an almost essential part of women's underclothing.

Most scoliosis patients were schoolgirls and young women.[3] Accordingly, physicians looked for a cause or causes of curvature in the physical attributes or patterns of living that differentiated

by Jane Farrell-Beck

young females from their male counterparts. Medical writers frequently blamed clothing for the curvature. The chief source of mischief was the corset, also called "stays." In the 1800s, when a girl approached adolescence, she was expected to adopt the clothing deemed appropriate to a genteel woman. That included being laced into whichever style of waist-constricting corset was fashionable at the time (Figure 2).

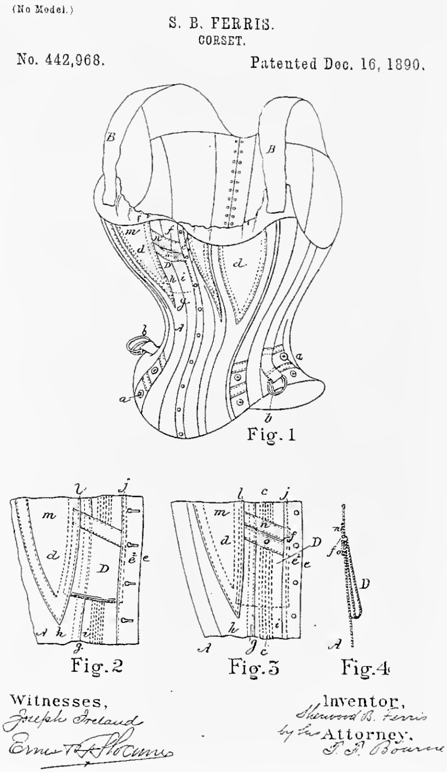


Figure 2. Illustration of a corset patented by Sherwood B. Ferris on December 16, 1890. Its contour was fashionable in the 1890s; the added shoulder straps made it a more "healthful" version of prevailing styles.

Clothing as a Spinal Hazard

The following quotations typify physicians' views of corsets. In 1819, Robert Wallace Johnson wrote that stays "confine the circular cavity of the thorax in its proper expansion." As a result, the thorax generally becomes "spheroidical, consequently one shoulder, and the breast . . . on the other side, projects or bulges out."[4] Thirty-eight years later, Russell T. Trall, a hydropathist (water-cure doctor), claimed that "a large proportion, and probably a very large majority, of American females over sixteen years of age have crooked spines" as a result of tight-lacing, "long draggling dresses, heavy skirts, and multitudinous flounces."[5] He illustrated his point with a figure showing a curve convex to the left; most scoliotic curves are convex to the right in the thoracic, or "dorsal," spine. Joseph H. Pulte remonstrated: "Any pressure in this age [girlhood] has a very injurious effect on the physical development. . . . Spinal and lung diseases are the frequent result of violations of this rule."[6]

Lucien C. Warner, author of a tract against tight-lacing, claimed that if the growth of a pubescent girl's hips and waist were inhibited by tight clothing "it prevents their normal development, and brings on spinal diseases and displacements and diseases of uterine organs."[7]

A British doctor, Eldred Noble Smith, took a more cautious line, saying: "[W]hen stiff corsets are used by growing girls, the full development of the dorsal muscles is seriously interfered with, and

weakness of the back is the natural consequence."[8] Lewis A. Sayre, an orthopedist, had offered negative evidence to connect corsets with curvature, writing: "We never see this deformity [lateral curvature] in that class of persons who use no restrictions to the full development of the muscles of the trunk by tight-lacing or bad dressing, and who are in the habit of carrying baskets, pails of water, or other articles, evenly balanced on their heads." Sayre may have been an early proponent of having girls walk with a book on their heads in order to develop erect carriage.[9]

Other apparel villains included "high heels" and off-the-shoulder dresses that required small girls to "hitch and turn their shoulders with a view to keeping up their dresses."[10] Charles Taylor warned against wearing clothing that impeded movement in any way. Such apparel would either weaken the muscles by handicapping them or would supplant the muscles and cause atrophy.[11] Bernard Roth maintained that "[T]he stoop of the scoliotic patient is often confirmed by closely fitting garments," including boys' and men's coats, collars, vests, and suspenders, as well as girls' and women's attire.[12]

A few physicians challenged the view that clothing was a spinal hazard. J. K. Mitchell, member of the Jefferson Medical College and editor of an American edition of R. W. Bampfield's *An Essay on Curvatures and Diseases of the Spine*, exonerated corsets because he observed thirteen times as many curvatures among uncorseted little girls as among corseted adolescents. Indeed, Mitchell favored the wearing of corsets "when girls are weak and incapable of keeping themselves steadily erect."[13] J. H. Coles, another British writer influential in the United States, admitted: "Cordially as I am disposed to join in a crusade against this evil [tight-lacing] . . . I doubt its being the origin of the majority of cases of lateral curvature, as is so frequently represented."[14] He weakened his first statement, however, by adding that tight-lacing distorted the ribs, which entailed distortion of the vertebrae. "At last," he concluded, "the spine becomes bent."[15] William Adams found little connection between tight-lacing and curvature. In fact, his most tightly-laced patient had less curvature than her siblings who did not wear overly-snug corsets.[16]

Second only to clothing among the debated causes of scoliosis was lack of exercise and general freedom of movement. Bernard Roth noted: "The much larger proportion of girls affected [by scoliosis], is due to the fact that girls do not enjoy, as a rule, one-fourth of the usual amount of physical exercise allowed to boys. Their muscles become weak; and, although they sit no worse than boys at their lessons, they have not sufficient strength to hold themselves erect, and to restore the balance of their curved backs out of school hours."[17]

Coles observed that spongy, soft bones—found in cases of scoliosis and due to tubercular illness or accident—were hardened by vigorous exercise. However, he also believed that such exercise would harm adolescent girls, who were already strained by the process of sexual maturation. Hence, girls had less opportunity than boys to avoid a permanent

curvature.[18] That view persisted well into the twentieth century.[19] Yet in 1894, Benjamin Lee refused to connect scoliosis with girlish fragility. He instead contended, "Many girls who develop this disease are singularly robust, vigorous, and well-developed."20

Closely related to the idea that muscular insufficiency caused scoliosis was the view that school life caused scoliosis. School seats and desks were decried as too hard, too narrow, too high, too low, or too uniform for varying sizes of children.[21] Such furniture allegedly fatigued the young pupils, who slouched when the teacher was not looking. The slouch became habitual and the habit became a fixed curve of the spine. School desks that required a twisted posture for writing were said to be another precipitating factor—as was rigid school discipline that forbade free movement and certainly did not provide young bodies with invigorating exercise. Quite possibly, the sloped desks popular in mid-twentieth-century schools were designed to rectify (literally) the perceived postural problem connected with training in the Palmer Method of penmanship.

The postural basis of scoliosis figured in the writings of Charles Ogilvie, who added long-continued piano playing and too-frequent horseback riding by "delicate girls" to the litany of harmful activities.[22] Charles McIntyre, director of gymnastics at Lafayette College of Philadelphia, implicated the popular sport of "lawn tennis" in scoliosis cases among fashionable young women of the 1880s. In his view, development of an ambidextrous serve was the remedy.[23]

Increasing scientific sophistication moderated physicians' ideas about external influences on scoliosis. Robert H. Lovett expressed the view that school conditions contributed principally to "false scoliosis," meaning bent postures assumable by a normal spine.[24] Arthur Steindler, a Viennese orthopedist who settled in Iowa, used engineering terms in 1929 to state a similar conclusion: "Weight bearing" or "dynamic stresses" acted on all spines, which might take a deformed position but seldom went into deformity.[25]

Most writers realized that scoliosis could develop from other diseases or conditions. A large medical contingent classified scoliosis as a disorder of weak or poorly balanced muscles.[26] Such doctors observed scoliosis following an attack of poliomyelitis or infection in the pleural cavity that caused muscular contractions in the chest. Different attributions appealed to doctors who believed in a skeletal etiology of scoliosis. Scrofula (enlarged lymph nodes in the neck) was often connected with scoliosis, as was rickets, a deficiency disease of the bones.[27]

Other orthopedists traced the off-center spine and asymmetrical trunk of a scoliotic patient to the unequal length of her or his legs. Mismatched legs contributed to "obliquity of the pelvis," which, in turn, tilted the spine. The appeal of that etiology was that the correction could be made easily, by building up one shoe to compensate for the shorter leg.[28] A few doctors related curvature to a tilted alignment of the head and shoulders assumed by people with astigmatism.[29]

A more subtle type of asymmetry, definable with the increasing use of "Roentgen" rays in the early twentieth century, was associated with hereditary or congenital irregularities of the spine. Those conditions included structural abnormalities of bony development, such as extra or absent ribs, a rib on a vertebra in the neck, a bifurcated rib, asymmetrical pairs of ribs, failure of formation of a portion of vertebra (regions of the spine that were abnormally high or low), vertebrae that had characteristics of two regions (e.g., lumbar and sacral spine), and miscellaneous muscular irregularities.[30]

Anatomy and Heredity

A few early orthopedists noticed that the onset of curvature coincided with the developmental changes of adolescence, a relationship that doctors still find significant.[31] In 1847, J. H. Coles observed curvatures that sometimes progressed rapidly and at other times stabilized. On those findings he based an argument against causation by the physical environment, which he believed to be relatively constant for an individual.[32] Eldred Noble Smith offered a long list of "predisposing causes" of scoliosis, among which were periods of rapid growth and premenarche status.[33] The anonymous writer of an editorial titled "Braces in Spinal Curvature" (later rebutted by A. M. Phelps) also connected scoliosis with "rapid growth."[34]

Heredity rarely appears among the listed causes of scoliosis, possibly because of scant understanding of hereditary traits before the twentieth century, but also because scoliosis might skip a generation or might not be manifested in all siblings.[35] The astute Coles commented in 1847 that a hereditary tendency "is a much more fruitful source of spinal distortions and diseases than is commonly supposed."[36] Both Smith and Lovett realized that heredity predisposed some people to scoliosis.[37] Hereditary cases of scoliosis were more widely recognized as the twentieth century progressed.

Perhaps the most difficult question for orthopedists was "what happened" to the scoliotic spine. External examination of patients revealed such aspects of the curvature as deviation of the spinous processes and differential prominence of the scapulae. Dissection of scoliotic cadavers contributed to further understanding of the abnormal anatomy of the scoliotic spine. New diagnostic techniques, including Roentgen or x rays, helped orthopedists recognize and quantify the severity of the curves.

An underlying theme in the debate was whether the muscles and ligaments held a precariously structured spine erect, or whether the column was stabilized by its own articulations.[38] In the 1700s and for most of the 1800s, muscular explanations of scoliosis were popular but proponents debated the details. Some cited weakness in the muscles, others stressed unequal strength in pairs of muscles.

Further disputes arose about whether the muscles contracted on the convex or the concave side of the curve. Charles Taylor described the spine bending like a bow under the tension of its string. Jules Guerin was the first to originate surgery based on the bowstring theory;

his procedure divided the muscles by tenotomy or myotomy. Such surgery fell out of favor by the 1880s, but his bowstring image persisted.[39] Robert Lovett refuted the bowstring analogy, finding that "the arrangement of the dorsal articulations is such as to cause a propensity to slump into a convex side rotation and lateral bending when the spine is left to its own inertia."[40]

By the late nineteenth century, simple bending models of the deformity were being revised. In 1888, Samuel Ketch defined "rotary" (*sic*) lateral curvature as "that lateral deviation of a portion of the whole of the vertebral column which has as its most constant factor the rotation, torsion, or twisting of the bodies or segments of the bodies of the vertebrae, with accompanying or consecutive alterations in the shape of the thorax."[41]

Ketch realized that rotation was present very early in the course of the deformity, as did Lovett, who observed torsion even in cases in which side-bending was all that was visible and the curve was still flexible. Lovett considered that the twist might be the original deformity, followed by side-bending. Using a live model, he had observed that rotation could not be corrected by passive manipulation when the spine was bent to the right, but that a lateral curve could be straightened without changing the rotation. Compensatory curves developed as the patient attempted to realign the shoulders with the pelvis. Lovett conducted his anatomical work at Harvard Medical School, assisted by Thomas Dwight and I. N. Hollis of that institution and H. O. Feiss of Cleveland.[42]

Adoniram Brown Judson offered the following explanation for why side-bending did not fully represent the state of the spine: "As the anterior section of the column departs farther from the median plane than the posterior section, the full extent of the deviation is not indicated by the curve seen in the line of the spinous processes."[43] Arthur Steindler subtly differentiated "segmental" from "intrasegmental" motion. In the first type, one section of the spine rotated against adjacent sections. In the second, lateral bending occurred because all vertebrae in the affected section moved sideways, with the vertebra at the apex of the curve moving farthest. Steindler compared the motion to the collapse of a spring.[44]

Treatment Goals

Such disparate explanations of scoliosis logically led to different goals in treatment. Physicians who perceived only the side-bending attempted to push the spine upright again. Those who recognized the rotation tried to reverse the torsion—a formidable challenge. Many twentieth-century orthopedists classified scoliosis by type or stage, reflecting the patient's degree of flexibility and the presence or absence of anatomic abnormalities in the vertebrae. Thus, scoliosis treated in the early "functional" stage could be prevented from "progression," an increase in the degree of curve. Gibney voiced the view of many doctors about advanced cases: "[I]t may safely be assumed now that no form of treatment yet adopted is equal to the correction of an osseous deformity."[45] Benefits that could be achieved for such patients were

relief of pain, training in better posture, more symmetrical muscular development, and "an ability on the part of the patient to hide the deformity."[46] Postural accommodation was the goal for Max Strunsky and also for Arthur Steindler, who attempted to produce compensating curves above and below the main curve.

Some therapy was directed toward less-immediate consequences, either for the patient or her future children. Doctors who believed in the inheritance of acquired characteristics struggled to correct scoliosis in young girls so that the deformity would not be passed on to their children.[47] Even doctors who rejected heritability of acquired traits nonetheless believed that a slumped posture would displace and compress the lungs and viscera, causing atrophy and preventing those organs from functioning correctly.[48] In such cases, treatment was intended to prevent later complications.

Braces and Jackets

Different types of physical support often played a part in the treatment of scoliosis, although formally-educated physicians seldom relied entirely on a brace or jacket. In 1842, J. H. Dorr used a suitably adjusted brace to "maintain . . . all that we get by extension," meaning stretching the spine while putting diagonal pressure on the curve. Dorr's brace, which was "scarcely, if at all, observable under the dress," allegedly relieved the posterior "stoop" and permitted exercise. Dorr also employed "friction shampooing" and percussion (essentially, massage) to improve circulation and flatten the curve.[49]

Forty-six years later, Samuel Ketch took an equally eclectic approach, although his goal was to unfold the spine, not just to remove the scoliotic curve by an opposing mechanical force. Ketch favored passive supports to sustain spinal corrections obtained by swinging, self-suspension, "automatic" movements, or "toning" exercises. His ideal brace was adjustable by the surgeon and, to some extent, by family members who helped the patient with exercise or bathing. Because it was lightweight, Ketch's brace prevented the excoriation of the skin that resulted from constant, heavy pressure.[50] Ketch admitted that no existing treatment could "cure" scoliosis because nothing de-rotated the vertebrae.

In the 1890s and early 1900s, doctors related treatment more explicitly to the stage of the illness or degree of progression of the curve. E. H. Bradford, working alone or with E. G. Brackett, recommended gymnastics and postural training for early or mild stages of scoliosis. For more advanced cases, they employed forcible corrections, sustained by various types of plaster "jackets" (Figure 3). Methods of forced spinal extension placed the patient in one of three positions—vertical, horizontal, or oblique—varying with the passage of time. Once the best possible correction was obtained, Bradford and Brackett prescribed lighter, removable corsets of various materials and exercises for maintenance of the improved posture. In his later papers, Bradford described a custom-made retainer brace in lieu of a corset.[51]

In 1898, Edward J. Farnum adjusted his treatments to individual patients. He handled mild cases by removing environmental conditions that favored the curvature (including poor posture and unequal length of legs), prescribing exercises to strengthen the weaker muscles. Farnum's supporter closely resembled a conventional corset, with metal reinforcements at the base, the center back, and under the arms. It was fitted with the patient either suspended or recumbent, to minimize the curvature. Farnum's passive device was to be worn only to relieve fatigue when the patient was upright.[52] Robert Tait McKenzie similarly regarded the plaster jacket or steel brace as mere retainers, used during the period of growth and removed for exercises, his main therapy.[53] During the 1910s, forcible correction of rigid scoliosis had fallen from favor because the pain and danger of injury to the patient outweighed possible benefits.

In the 1920s, Armin Klein argued that exercise could "mobilize" the unused or tightened ligaments and muscles, allowing local control of respiratory muscles. Then he applied a perforated plaster jacket, into which could be inserted pads that were placed to exert differential pressure on the chest wall. He intended, by composite treatment, to balance both sides of the torso through greater use of one lung than the other. Objecting to surgery that fused the spinal vertebrae, Klein advocated using a lengthy series of braces and removable or nonremovable jackets, combined with exercise to establish a stable spine and strong muscles until patients reached the supposed safety of their twenties.[54] Samuel Kleinberg, in the 1920s and 1930s, also embraced a lengthy treatment. He prescribed four to eight weeks of hospitalization in traction. Some patients underwent fusion surgery; most were treated with gymnastics and a plaster, leather, or celluloid corset. Kleinberg eschewed braces because they were too easily tampered with and made ineffectual.[55]

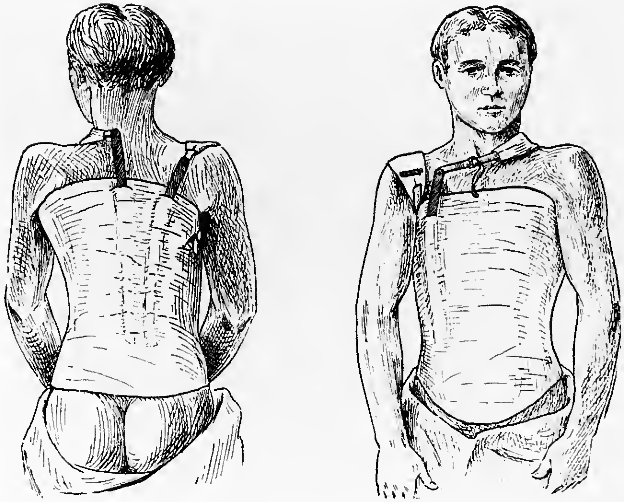


Figure 3. Rear and front views of a plaster "jacket" developed by E. H. Bradford and E. G. Brackett in the 1890s.

Inconvenience, Pain, and Atrophy

Each type of spinal support enjoyed a period of popularity, yet each had drawbacks, some rooted in the limits of contemporary technology, others in the variability and intractability of scoliosis itself. Various types of rigid support,

analogous to a plaster cast, commanded a following in the late nineteenth and early twentieth centuries. The so-called "jackets" were used in the hope that if the spine could be immobilized in a straightened or "corrected" position, the correction would remain when the jacket was removed. Usually a jacket was applied with the patient suspended vertically. To alleviate patients' fear, self-suspension was employed as an exercise by both Benjamin Lee and Lewis Sayre; nonetheless the process put painful pressure on the neck and jaws, leading a few orthopedists to adopt hammock suspension or a seated posture with a system of pulleys.[56] A jacket was no quick fix, often requiring months or years of wear. Jackets had to be changed frequently in order to accommodate the body's growth and alternations in shape.

Physicians' goals for using jackets evolved over the decades. In the 1870s, plaster jackets were intended simply to hold the spine upright. By 1904, Compton Riely enumerated three objectives: to counteract pelvic and abdominal asymmetry, in turn correcting the ribs; to remove swayback and stooped shoulders; and to remove the curvature by de-rotation of the vertebrae.[57] Recognizing the limits of what plaster could accomplish, Michael Hoke and C. R. Andrews set metal pressure plates in the jacket, applying asymmetrical pressure and causing the lungs to expand more on the flattened side of the torso and less on the enlarged side. Such pressure also helped to rebalance both sides of the torso and improve the patient's appearance.[58] Although Edville G. Abbott

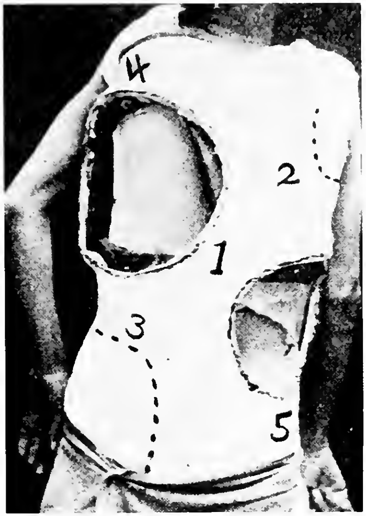


Figure 4. Plaster jacket with "windows" for insertion of layers of padding.

continued to treat the jacket as the retainer of a forcibly corrected spine, many practitioners applied it actively, using "windows" cut in the plaster for insertion of pads (Figure 4). The windows could be augmented or reduced to adjust pressure on the outcurving parts of the torso.[59]

Even in their days of greatest acceptance, plaster jackets had well-known drawbacks. Although the patient could not tamper with the jacket, neither could the orthopedist check the status of the curvature without removing the cast.[60] Early forms did not provide the graduated local pressure that orthopedists hoped would correct the curve. Lovett maintained that curvatures of the neck and upper back would respond only to a jacket that extended over the head.[61]

Being painful to apply, jackets were often put on more quickly than accurately. Jackets were difficult to make, involving a long list of supplies and tools.[62] Opponents of jackets asserted that they caused muscular atrophy, a consideration that shortened the period of use even among proponents.

From the point of view of the patient, jackets were miserable to wear: heavy, chafing, hot in summer, and conducive to body odors. Plaster of Paris, the usual material of the jacket, gradually disintegrated, sifting powdery grit through the wearer's clothing.[63] Jackets became loose, shifted position, and ceased to support the spine.[64] Windows cut in later jackets reduced the weight and provided apertures for adjustable padding and for cleansing massages with alcohol and talcum powder. Truslow, for example, cited Gibney as changing the shirt under the cast without removing the cast.[65]

To the orthopedists' frustration, the spinal column proved more resistant to a corrective cast than did the foot, knee, shoulder, or other joints. The spine's intimate connection to the brain seems to have made its functioning more complex. Furthermore, the interlocking of vertebrae with each other and with the ribs complicated the problem of immobilization. Nonremovable jackets gradually ceased to be used.

Braces entered into the treatment of scoliosis long before the 1800s and remain important in scoliosis therapy up to the present. Some physicians used braces in lieu of plaster jackets; others employed a brace as a replacement for the jacket in later stages of treatment. More varied than jackets, braces were often assembled from metal uprights and hip bands, to which were attached various metal pressure plates, pads, and straps of leather or woven textiles (Figure 5). The metal strips of Charles F. Taylor's "spinal assistant" rested on either side of the spinal column as an attempt to prevent sideways bending.[66]

Both R. Tunstall Taylor and E. H. Bradford employed braces as retainers of corrections attributed to exercise and manipulation, but most physicians who used braces had a more active treatment role in mind.[67] Some braces were designed to put diagonal pressure on the protruding shoulder blade or ribs, raise the lower shoulder, or untwist the body.[68] Braces were believed to transfer some of the weight of the head and upper torso from the spine to the pelvic

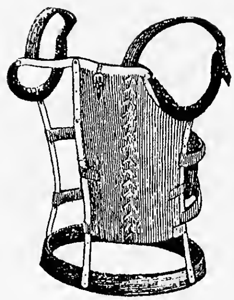


FIG. 738.

Fig. 738 represents another style of Lateral Curvature Brace. For measurements, see Fig. 716.

Prices—$12.00 to $20.00.

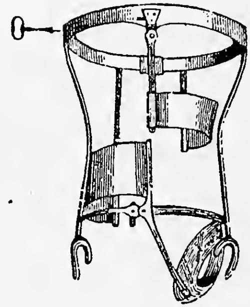


FIG. 739.

Fig. 739--This cut represents apparatus adapted for a double Curvature of the Spine, with attachment for correction of Depression of the shoulder. It is adjusted by a screw with key. State the position of deformities and age and sex of patient. For measurements, see Fig. 716.

Prices—$30 to $50.00.

Figure 5. Scoliosis braces featured in an 1894 physicians' supplies catalog of the Detroit Pharmacal Company.

girdle.[69] Physicians who used braces accepted the fact that exercise by itself could not remove a curvature or prevent its progression.

Braces offered several advantages to both the orthopedist and the patient. The physician could readily observe changes in the patient and could adjust various parts of the brace as required. Moreover, braces were thought to encourage thoracic respiration, formerly believed to be more healthful than abdominal breathing.[70] Other advantages accrued to the patients. A brace offered slightly more freedom of movement than did a plaster jacket. Braces were compatible with bathing, usually weighed less than plaster, and could be made inconspicuous to wear.[71] On the debit side, braces were more expensive than most other types of support because they were complicated to make. Some braces proved heavy, bulky, and abrasive to the skin. Samuel Kleinberg objected to braces because they needed precise adjustment, which was difficult to achieve but easy for a patient to undo.[72] Finally, doctors fumed about the role of mere "instrument-makers" producing and selling braces independently.

Medical Corsets

Both jackets and braces were designed purely as medical devices, but a widely-used support borrowed the shape and function of an article of everyday dress—the corset. Notwithstanding medical fulminations against tightly-laced corsets, orthopedists employed corsets made from an array of materials to support scoliotic spines. Prescription corsets resembled fashionable ones in their lacing or hinging, as well as fasteners. Medical corsets could be removed easily and were worn over a knitted shirt or woven undergarments, like their fashionable counterparts. Some medical corsets had linings—linen for summer and canton flannel (napped cotton) for winter.[73]

Scoliosis corsets, often called "removable jackets," came in a myriad of materials: plaster of Paris, leather, woven wire, celluloid, felt saturated with a gluey substance for pliability, layered strips of paper or wood, perforated aluminum, and even woven textiles.[74] Some designs were reinforced by metal rods, strips, or spring steel similar to that used in bustles. Like plaster jackets and prescription braces, orthopedic corsets were custom fitted. Some corsets were fitted over a plaster cast of the patient's torso.[75] If the corset was to act as a retainer, it was shaped over the body in an "extended" vertical position. Charles Taylor prescribed corsets only for "middle-aged ladies" whose curvature was beyond correction but could be masked by such a prosthesis.[76] Extension was of little use in long-standing curvatures.

Corsets offered many advantages to the patient. They could be removed and adjusted at will, did not interfere with bathing, and—being lighter and less bulky—allowed the user to wear ordinary clothing.[77] Also, corsets were markedly cheaper than braces, $1.25 versus $18 to $50.

Some corsets required very complicated fitting. The Russo-Austrian "wood corset" adapted by A. M. Phelps, for example, required some twenty items to

construct, counting materials and tools.[78] That design featured overlapping layers of vertical, horizontal, and diagonal strips of wood. Doctors with neither the time nor skill to prepare the corset could create a cast of the patient's torso and send it with an order to Phelps's hospital workshop at the Post-Graduate School and Hospital of New York.[79] Of similar complexity was a corset of paper and jute produced by J. Marshall Hawkes (Figure 6).[80]

Phelps also experimented with perforated aluminum, which was alleged to be lightweight and wearable while bathing; the corset would not break down like paper or wood but could scarcely have been comfortable (Figure 6).[81] A metal corset could be used for long-term bracing of intractable cases. Metal usually reinforced the front and back openings of conventional corsets in order to stabilize the fastenings and force the wearer to stand erect. Farnum modified the ordinary cloth-and-whalebone corset by adding a steel base and upright strips; he custom-fitted his patients in either suspended or recumbent positions.[82]

The patients of Paul M'Ilhenny were enjoined to round-the-clock wearing of a plaster-of-Paris corset. Removal was limited to periods of bathing and exercise, but that stricture lasted only for six to eight weeks, followed by wearing just by day.[83] In 1910, Zabdiel B. Adams used an almost modish corset (Figure 7) as support after surgery on the "transverse process" of a vertebra.[84] By that year, fashionable corsets were much less constricted at the waistline. They were designed to raise the bust and compress the hips into a lithe line. David Silver's plaster corsets featured both windows and felt pads; his corsets worked much like the jackets described above, but were removable.[85] Often the corset extended over the shoulder and around the neck.

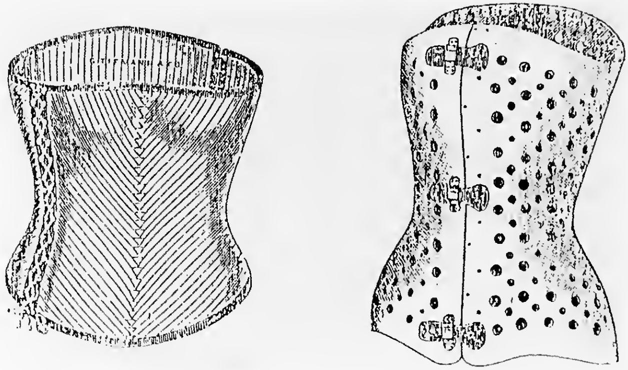


Figure 6. Two scoliosis innovations of the mid-1890s: at left, a paper corset developed by J. Marshall Hawkes; at right, a perforated aluminum corset designed by A. M. Phelps.

Nonprescription Devices

People with neither the money, time, nor inclination to pursue orthodox medical treatment for scoliosis could purchase nonprescription devices that purported to cure curvatures. Such essentially quack treatments raised the hackles of duly educated orthopedists. Even a strictly "popular" medical writer, George Naphys, warned his readers against "the many 'braces' and 'stays' which are advertised."[86] Both Lovett and Bradford wrote articles denouncing commercial supports.[87] Undoubtedly, many other physicians said or wrote as much privately. Nonetheless, the entrepreneurs flourished.

Some nonprescription devices, patented and advertised as braces, were equipped with straps, elastics, and pads to pull back the wearer's shoulders. One type, advertised for men and boys, resembled suspenders. (In fact, suspenders were often known as "braces.") Women's and girls' models added a waistband to which petticoats could be fastened. Other styles had more extensive back pieces with stiffening materials and straps to hold the shoulders in place (Figure 8). Corsets, differing only slightly from fashionable examples, constituted another class of commercial supporters claiming to help scoliotics (Figure 9). Usually made of nonrigid materials (except for metal or whalebone strips or "stays"), they were intended for women and girls—unlike medical corsets, which men might also wear. Finally, a handful of inventors secured patents for what are now called brassieres, with claims to straighten or support the back (Figures 10 and 11).

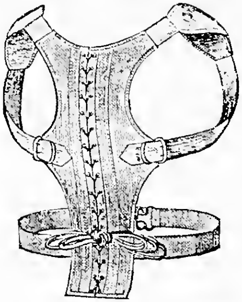
Some nonprescription supporters went no further than the patent office. Others, notably the designs of Philo Burt Shelden (later spelled "Sheldon"), were modified, presumably produced, and advertised in women's and family magazines, including *The Delineator*, *Harper's Bazar*, *Vogue*, and *Scientific American* between 1901 and 1926. The complex mechanism patented in 1893 under the name Philo Burt Shelden was succeeded in 1901 by a simpler article, manufactured by the Philo Burt Company in Jamestown, New York. In 1909 Sheldon claimed "14,000 cases of spinal curvature troubles relieved and benefitted by the Sheldon Spinal Appliance . . . and our treatment," leaving no doubt of the intent of his product (Figure 12).[88]

Pharmaceutical catalogs also carried information about the Knickerbocker brace, as well Dr. Gray's and Cutter's braces, to name a few. Such evidence points to a regular clientele for commercial back straighteners and supporters.

Figure 7. Corset used by Z. B. Adams after 1910 as a postoperative brace. The silhouette resembles that of fashionable corsets of the 1890s.

BRACES, SHOULDER.

SHOULDER BRACES.



LADIES' LACED OR CORSET BACK BRACE.

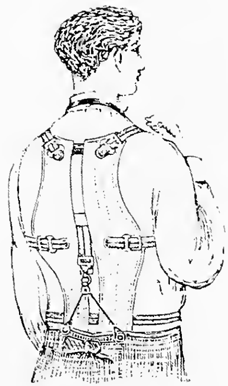
Made of fine corset jean, white elastic web, and stout nickled buckles. Made in three sizes

Ladies'	per doz	$20 00
Misses'	per doz	20 00
Cutter Shoulder Braces	per doz	21 00

GRAY'S BRACES.

Ladies' made in four sizes.

Ladies'	per doz	$21 00
Gents'	per doz	35 00
Youths'	per doz	33 00
Boys'	per doz	30 00



KNICKERBOCKER BRACES.

When ordering, state whether Ladies', Gents', Boys' or Girls' style is wanted.

		Per doz.
No. 1.	Ladies' or Gents', sizes 28 to 42	$17 00
No. 2.	Ladies or Gents', sizes 28 to 42	13 00
No. 3.	Ladies' or Gents', sizes 28 to 42	9 00
No. 3.	Boys' or Girls', sizes 20 to 26	9 00

Figure 8. Various styles of commercial braces from the 1903 pharmaceutical catalog of F. W. Braun & Company.

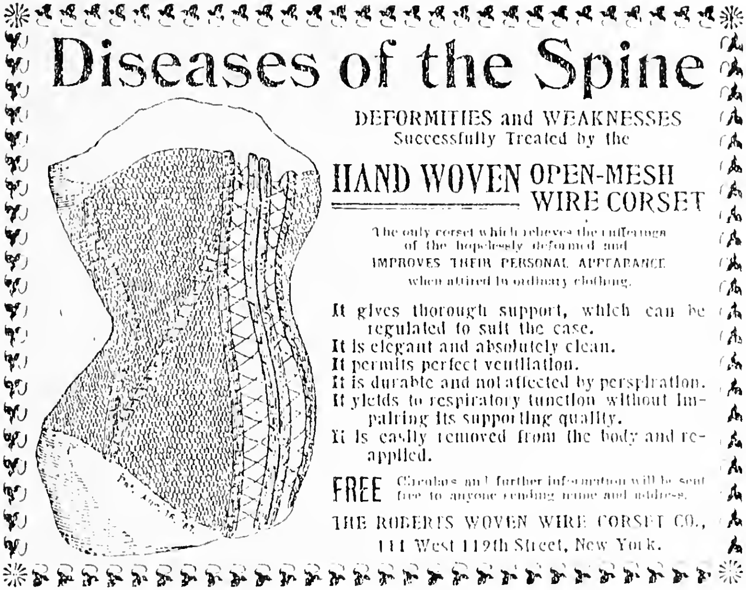
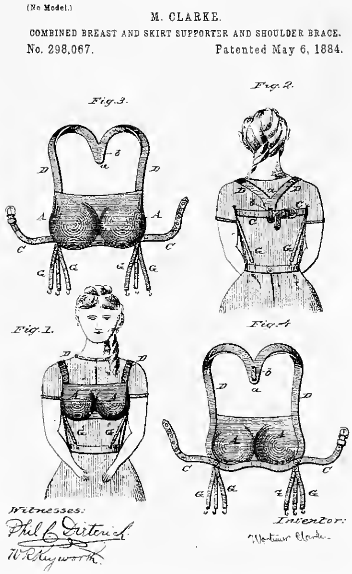


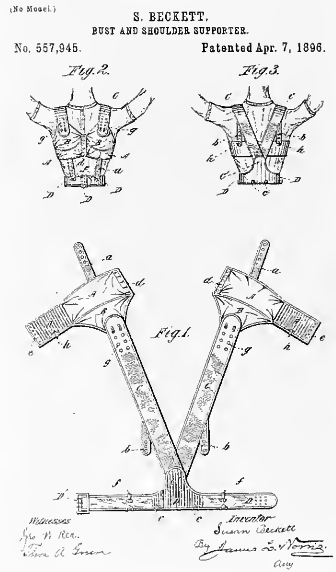
Figure 9. Woven wire corset from an 1897 advertisement by the Roberts Woven Wire Corset Company.

After about 1916, however, the advertisements decreased sharply. Some—including the Victory brand of shoulder brace—seems to have met commercial defeat, despite the substitution of fashionably dynamic poses for the usual static stance of figures modeling braces.[89] Men's suspender-style braces appeared sporadically, and pharmaceutical catalogs continued to show some brands into the late 1930s.

Brassieres seem to have offered women light support for the back as well as the breasts. Early advertisements had shown commercial braces being worn with union suits, corsets, or corset covers, but not with brassieres. Either their functions overlapped or the two garments could not be worn together. As the variety and volume of brassiere advertising increased, especially in the early twentieth century, advertising for commercial braces almost disappeared.

Although nonmedical braces and corsets ultimately lost customers, they enjoyed a surprisingly consistent following for many decades. They could scarcely have helped alleviate or arrest scoliosis, however, nor were they well fitting. Of necessity, nonprescription devices were symmetrical, because the manufacturers did not obtain customers'





Left, ***Figure 10. Illustration of Mortimer Clarke's "Combined Breast and Skirt Supporter and Shoulder Brace," patented on May 6, 1884. His seems to have been the earliest brassiere patented in the United States.***

Right, Figure 11. Susan Beckett's design for the "Bust and Shoulder Supporter," patented in the United States on April 7, 1896.

measurements. Indeed, they were often sold to mail-order purchasers, sight unseen. Such devices exerted equal action on both sides of the wearer's back; they could not remove asymmetry, let alone derotate the vertebrae. Nevertheless, braces like the Philo Burt model must have satisfied their wearers, for his company continued to advertise in national magazines for more than twenty-five years. Perhaps the Burt product met the needs of scoliotics who had mild, nonprogressive cases that would have stabilized without treatment. Other customers might not have had scoliosis at all, merely stooped postures that responded to bracing. Perhaps, too, the

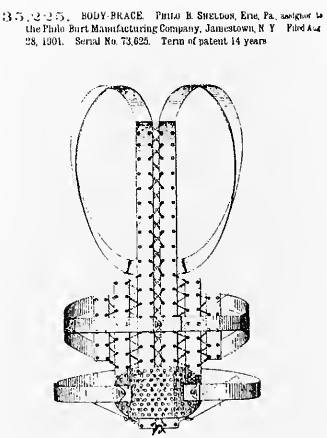


Figure 12. Design patent obtained by Philo B. Sheldon for a "Body-Brace," October 22, 1901.

difficulty that legitimate physicians encountered in helping scoliotics drove frustrated sufferers to commercial quacks.

During the later 1910s and 1920s, changes in clothing for women and, to a lesser degree, for men, created deterrents to wearing nonprescription braces and spinal corsets. Men's suits evolved from the blocky proportions of the 1890s and early 1900s to a lean line, which would have made a brace conspicuous. In the 1910s, women's apparel traded its stiff silhouette for supple shapes that skimmed the torso—a trend that accelerated in the 1920s. Fashion even espoused the "debutante slouch" posture, in contrast to the rigid or arched-back stance of previous decades. Mild forms of scoliosis, constituting the majority of cases, could scarcely be detected with such styles and posture.

Unlike nonprescription devices, medical braces persisted after the 1930s. Researchers developed the Milwaukee Brace as a conservative treatment for progressive curves in adolescents. In the early 1900s, Russell Hibbs pioneered spinal fusion to arrest curve progression surgically. Variations of rigid bracing and surgical fusion are present-day mainstays of treatment for scoliosis. The commercial braces have left behind their progeny, however, in many current designs for "sports brassieres."

■

Notes

1. William P. Bunnell, "Natural History of Idiopathic Scoliosis," *Clinical Orthopaedics and Related Research* 229 (April 1988): 20–25.

2. R. Tait McKenzie, *Exercise in Education and Medicine*, 2nd ed. (Philadelphia: W. B. Saunders, 1909), 275; Robert W. Lovett, *Lateral Curvature of the Spine and Round Shoulders* (Philadelphia: P. Blakiston's Son & Company, 1912), 115.

3. Benjamin Lee, "The Importance of Early Diagnosis in Lateral Curvature of the Spine," *Transactions of the Medical Society of the State of Pennsylvania* 25 (1894): 375.

4. Robert Wallace Johnson, *The Nurse's Guide and Family Assistant*, 2nd Am. ed. (Philadelphia: Anthony Finley, 1819).

5. Russell T. Trall, *The Illustrated Family Gymnasium* (New York: Fowler and Wells Publishers, 1857), 25–27. Hydropathists, or water-cure doctors, used various types of baths and consumption of copious amounts of water as a central part of their therapy for a range of diseases.

6. Joseph H. Pulte, *Woman's Medical Guide* (Cincinnati: Smith and Worthington, 1853), 61. Pulte was a "regular," not sectarian, doctor.

7. Lucien C. Warner, *A Popular Treatise on the Functions and Diseases of Women* (New York: Manhattan Publishing Co., 1874), 55.

8. E. Noble Smith, *The Surgery of Deformities* (London: Smith, Elder & Company, 1882), 177.

9. Lewis A. Sayre, *Lectures on Orthopedic Surgery and Diseases of the Joints* (London: J. A. Churchill, 1876), 498. The book was based on Sayre's lectures at Bellevue Hospital Medical College, in winter 1874–1875.

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13. R. W. Bampfield, *An Essay on Curvatures and Diseases of the Spine*, ed. J. K. Mitchell (Philadelphia: E. Barrington & G. D. Haswell, 1845), 114–15, footnotes. The first edition of Bampfield's work was published in 1824 in London.

14. J. H. Coles, *Spinal Affections and the Prone System of Treating Them . . .*, 2nd ed. (London: Houlston & Stoneman, 1847), 52–53.

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16. William Adams, *Lectures on the Pathology and Treatment of Lateral and Other Forms of Curvature of the Spine* (London: J. and A. Churchill, 1882), 149.

17. Roth, "Treatment of Lateral Curvature," 691.

18. Coles, *Spinal Affections*, 68–69.

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21. Meyer Solis-Cohen, *Life Knowledge* (Philadelphia: Uplift Publishing Company, 1909), 51–55; John B. Brown, "Curvature of the Spine" (letter to John C. Warren), *Boston Medical and Surgical Journal* 18 (1824): 139–42.

22. Charles Ogilvie, "The Treatment of Pott's Disease and of Rotary Lateral Curvature by the Plaster of Paris Jacket and the Aluminum Corset," *New York Medical Journal and Philadelphia Medical Journal* 82 (July 29 and Aug. 5, 1905): 209–13, 265–69.

23. Charles McIntyre, "'Lawn-Tennis' Back," *Philadelphia Medical Times* 15 (Feb. 21, 1885): 387–88.

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25. Arthur Steindler, *Diseases and Deformities of the Spine and Thorax* (St. Louis: C. V. Mosby Company, 1929), 145.

26. Henry R. H. Bigg, *Spinal Curvature* (London: J. & A. Churchill, 1882), 14; Samuel Kleinberg, *Scoliosis* (New York: Paul B. Haeber, 1926), 101.

27. Coles, *Spinal Affections*, 68–69; Smith, *Surgery of Deformities*, 176; A. M. Phelps, "Braces in Spinal Curvature: A Discussion of a Few Points Found in an Editorial of September 10, 1898," *Journal of the American Medical Association* 31 (Nov. 12, 1898): 1184–86; Paul M'Ilhenny, "Scoliosis: Its Prevention and Treatment," *Lancet-Clinic* 98 (July 20, 1907), 55–61. The softness and deformation of the bones in rickets arises from inability to assimilate and use calcium and phosphorus, due to insufficient consumption of vitamin D or inadequate exposure to sunlight.

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31. For a discussion of predictive and nonpredictive factors for scoliosis, see Bunnell, "Natural History," 220–25, and Bigg, *Spinal Curvature*, 37.

32. Coles, *Spinal Affections*, 56.

33. Smith, *Surgery of Deformities*, 176–77.

34. Phelps, "Braces in Spinal Curvature," 1184–86; the original editorial appeared in *Journal of the American Medical Association* 31 (Sept. 10, 1898): 610–11.

35. Richard Barwell, *The Causes and Treatment of Lateral Curvature of the Spine*, 4th ed. (New York: Macmillan & Co., 1889), 34.

36. Coles, *Spinal Affections*, 79.

37. Smith, *Surgery of Deformities*, 177; Lovett, *Lateral Curvature*, 96; J. S. Sherman, "Lateral Curvature of the Spine," in *Lectures on Orthopedic Surgery, Chicago Medical College* (Chicago: Chicago Medical Examiner, 1869), 77–83.

38. Phelps, "Braces in Spinal Curvature," 1185.

39. Jules Guerin was the originator of this view; his treatment consisted of surgery to divide the muscles by tenotomy or myotomy. Such surgery fell out of favor by the 1880s, but the bowstring image persisted. Taylor, *Theory and Practice*, 73–76.

40. Lovett's remarks were reported in Steindler, *Diseases and Deformities*, 144.

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42. Robert Lovett, "The Element of Torsion in Lateral Curvature of the Spine: Its Place in the Cause and Treatment," *Boston Medical and Surgical Journal* 149 (Aug. 6, 1903): 144–49.

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44. Steindler, *Diseases and Deformities*, 146.

45. V. P. Gibney, "The Prognosis of Lateral Curvature in Young Girls," *Medical Record* 38 (Aug. 23, 1890): 206.

46. Ibid., 206; Max Strunsky, "The Treatment of Progressive Scoliosis," *Medical Record* 74 (June 4, 1910): 961; Kleinberg, *Scoliosis*.

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53. McKenzie, *Exercise in Education,* 314.

54. Armin Klein, "Treatment of Structural Scoliosis at Massachusetts General Hospital," *Journal of the American Medical Association* 78 (Feb. 11, 1922): 418–21; and Klein, "Subsequent Report of the Treatment of Scoliosis at the Massachusetts General Hospital," *Journal of Bone and Joint Surgery,* n.s. 6 (1924): 858–75.

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56. Sayre, *Lectures on Orthopedic,* 500–1; Sayre cites Lee and describes his own use of the method. See also Richard Barwell, "On a Method Better than Suspension of Applying a Plaster Jacket," *Lancet,* Apr. 9, 1892, 1: 792–93; N. P. Dandridge, "The Hammock Suspension in the Application of the Plaster Jacket in the Treatment of Spinal Curvature by Davy's Method," *Cincinnati Lancet and Clinic,* n.s. 6 (Jan. 11, 1881): 73–85 (that treatment was adapted from "Mr. Davy, Surgeon to the Westminster Hospital," substituting an American-designed hammock).

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60. Charles F. Stillman, "Continuous Extension in Spinal Curvature: A Question of Priority," *Medical Record* 15 (1879): 189–90.

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65. Walter Truslow, "Treatment of Structural Scoliosis," *American Journal of Orthopedic Surgery* 8 (November 1910): 288–89.

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67. R. Tunstall Taylor, "A New Brace as an Adjunct in the Treatment of Severe Cases of Scoliosis," *New York Medical Journal* 66 (Oct. 30, 1897): 586–89; and *Surgery of the Spine and Extremities* (Philadelphia: P. Blakiston's Son, 1924): 254; E. H. Bradford, "Spinal Curves in Growing Children," *Boston Medical and Surgical Journal* 184 (May 19, 1921): 512–18.

68. R. T. Taylor, "New Brace," 588; Bigg, *Spinal Curvature,* 50, 52–53.

69. R. T. Taylor, "New Brace," 589.

70. Smith, *Surgery of Deformities,* 190.

71. R. T. Taylor, "New Brace," 589; Bradford, "Spinal Curves," 512–18.

72. Samuel Kleinberg, "Symposium on the Disorders of Children: Management of Structural Scoliosis," *Medical Record* 142 (Dec. 18, 1935): 537.

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and Lateral Curvature," *Medical Record* 15 (1879): 595–98.

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77. David Silver, "A Removable Plaster Corset," *American Journal of Orthopedic Surgery* 9 (1911–1912): 703–7.

78. Phelps, "Wood Corset," 37–38.

79. Ibid., 41.

80. Hawkes, "Injury to the Spine," 57–59.

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83. M'Ilhenny, "Scoliosis," 55–61.

84. Zabdiel Boylston Adams, "A Case of Scoliosis Relieved by Operation on the Transverse Process of One of the Vertebra," *American Journal of Orthopedic Surgery* 9 (November 1910): 299–305.

85. David Silver, "Removable Plaster Corset," 703–7.

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87. Lovett, *Lateral Curvature,* 168, 363–65; "Round Shoulders," *Boston Medical and Surgical Journal* 139 (Oct. 13, 1898): 363–65; Bradford, "Management of Spinal Curvature," 606.

88. *The Delineator* 74 (October 1909): 366.

89. Peter Van Schaack & Sons, *Annual Price Current* (Chicago, 1916), 1116.

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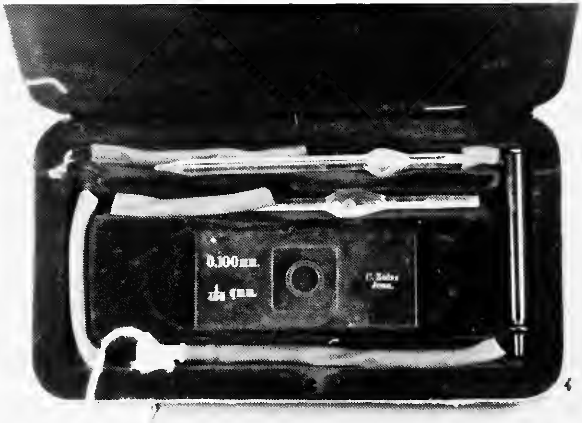


Figure 1. Hemocytometer, circa 1900, showing Zeiss counting chamber with circular depth trough, red-cell and white-cell diluting pipettes, and rubber tubing. (Courtesy of the Historical Division, Cleveland Medical Library Association)

The most commonly used hemocytometer of the early twentieth century was the Thoma-Zeiss style instrument. It was crafted from a thick piece of glass upon which a round glass lumina (i.e., a circular piece of glass with a hole in its center) had been cemented and a distinctive grid had been etched.

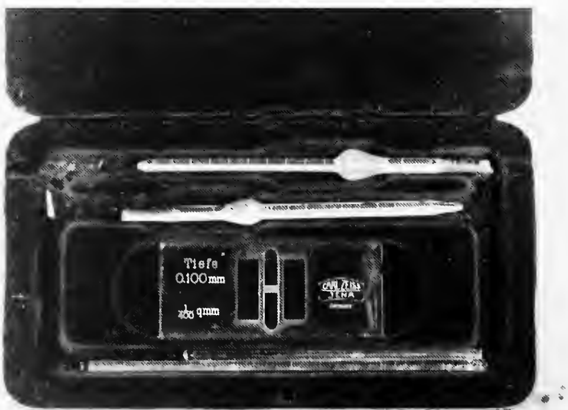


Figure 2. Hemocytometer, circa 1915, showing Zeiss counting chamber with raised glass supports and red-cell and white-cell diluting pipettes. (Courtesy of the Historical Division, Cleveland Medical Library Association)

The Evolution of the Progressive-Era Hemocytometer

The hemocytometer (Figures 1 and 2) is one of the oldest laboratory instruments utilized by clinicians on a continuous basis since the end of the nineteenth century. It consists of a glass slide on which a ruled grid has been etched, a cover glass, and one or two pipettes used to dilute the blood samples. The hemocytometer can be defined, as it was in 1899, as an "apparatus for diluting the blood and counting the contained corpuscles."[1]

Over the years, technology has dramatically affected the clinician's world: microscopes have evolved into more powerful, even automated, tools for viewing cells, and hemoglobinometers (devices for measuring hemoglobin or "the respiratory pigment of erythrocytes") have been incorporated into automated blood analyzers.[2] Yet remarkably, the basic design of the hemocytometer has not changed in almost one hundred years. It has not been completely abandoned by the laboratory practitioner. Although at times the instrument may be relegated to the corner of a drawer, it is still utilized to recheck ambiguous results and to count other cellular material in body fluids. In short, the natural simplicity of counting red and white blood cells with a hemocytometer has not radically changed over the years, and that fact helps explain the durability of the instrument.

The development of the hemocytometer can be divided into two phases. The first involved the actual forging of the counting chamber, while the second revolved around the selection of the pipettes, counting grids, and auxiliary paraphernalia that were critical for its operation. Efforts were constantly ongoing among numerous clinicians to upgrade the pieces of equipment that were necessary for the job of cell counting.

The Counting Chamber

Probably the first clinician to appreciate the significance of being able to quantify the number of red cells in a minute, measured volume of blood was Pierre-Adolphe Piorry (1794–1879), a clinical professor of medicine at the School of the Paris Hôpital. In addition to being one of the pioneers in the field of thermometry, Piorry also strongly advocated using the microscope as a tool in clinical medicine, and he stressed the value of microscopic examinations of

by Jack David Davis

secretions and the blood for evidence of disease.[3]

The technique proposed by Piorry for counting red cells was tucked away in a footnote to his 1847 *Traite de Médecine pratique.* Basically, Piorry suggested adding drops of blood to a solution of sodium sulfate, mixing the two together, and then examining the volume of blood that adhered to the sharp end of a needle. By following that procedure, Piorry wrote that "one would be able to evaluate (but only approximately) the relative proportions presented by different kinds of blood."[4] Physician-historian W. D. Foster notes that it is not known if Piorry put his suggestion into practice, but Piorry himself says that he was not taken seriously because the practitioners of the day, already struggling to incorporate stethoscopy into their practices, saw no practical rewards in applying microscopic technique to clinical medicine.[5]

In the milieu in which Piorry worked, French medicine was at its apogee and French investigators were acutely interested in studying the blood and its associated disorders. As early as 1835, Gabriel Andral (1797–1876), a member of the staff of the Charité Hôpital, a member of the Royal Academy of Medicine, and a professor of general pathology at the Paris Hôpital school, coauthored an article in the *Dictionaire de Médecine et de Chirurgie pratique* in which he discussed the phenomena of blood coagulation, anemia (a decrease in red cells), and polycythemia (hyperemia, or an increase in red cells). He also investigated the physical properties of blood—including color, taste, odor, and the role of blood in the disease process. Eight years later, he elaborated on his research in his *Essai d'hématologie pathologique,* a definitive study of hematology.[6]

The significance of Andral's work, especially as it applied to Piorry, was his attempt to characterize blood in numerical terms. Working essentially from chemical means, Andral calculated the weight of the globules, the fibrin, the water, and the solid residue in the serum. The significance of being able to measure the number of red cells in a known quantity of blood so as to discriminate between normal and abnormal conditions (anemia or polycythemia) did not escape Piorry's notice.[7]

Another important person in the early development of French blood-counting philosophy was Alfred Donné (1801–1878), an outstanding microscopist. Donné strongly promoted the use of the microscope in medical practice, and he published his *Cours de Microscopie* in 1844 along with an atlas that employed the new process of photomicroscopy. Since Donné, Andral, and Piorry were contemporaries, it follows that Piorry more than likely borrowed from Piorry's enthusiasm for microscopy and Andral's preoccupation with quantification in proposing to determine the number of red cells that were contained on the sharp end of a needle. Donné's goal was to numerically distinguish between different disease states, such as anemia and polycythemia. But, like Donné and his microscope, Piorry's suggestions for improving the status of medicine by means of a technologically advanced process

like blood counting were largely ignored. Among physicians at the Paris Hôpital school, Piorry, Andral, and Donné had been motivated by an academic desire to learn more about both the diagnostic signs of blood diseases and the microscopic characteristics of the blood cell itself. By the 1850s, however, the Paris Hôpital school had begun to give way to the ascendancy of German medicine—i.e., laboratory medicine—and a new chapter in the history of blood counting was about to begin.[8]

Early Cell-Counting Techniques

Laboratory medicine replaced sense impressions with numbers. For the first time, a large number of full-time, professional scientists were employed to teach and to do research in the field of physiology. The first person to actually devise an exact method for counting red blood cells was Karl Vierordt (1818–1884).[9]

Vierordt began his professional career as a general practitioner in the town of Karlsruhe, capital of Baden. In 1849, he was appointed an extraordinary, or associate, professor of theoretical medicine at Tübingen, and it was at that Swabian university that he began his scientific studies of physiology. During his years at Tübingen, Vierordt invented the sphygmograph, which was used to trace the human pulse, and the haemotachometer, with which he attempted to measure the rate of blood flow in the arteries. He also used a spectrophotometric technique to measure the hemoglobin content of the blood. Vierordt was a prime example of a general practitioner who evolved over time into a scientific experimenter. Between 1842 and 1885, he published 116 articles on different aspects of physiology.[10]

Motivated primarily by an avid interest in science—i.e., physiology—Vierordt in 1852 published "Neue Methode der quantitativen mikroskopischen Analyse des Blutes" (New Method of Quantitative Microscopic Analysis of the Blood), in which he first described an exact method for counting blood cells. Vierordt's "microvolumetry" method made use of a very fine capillary tube. After the internal diameter of the capillary tube was accurately measured using a micrometer, he drew a drop of blood up into it; he then measured the length of the column of blood within the capillary tube by means of a glass micrometer set on the microscope stage. With that procedure, Vierordt was able to calculate the exact volume of blood that he was working with.[11]

Next, Vierordt blew out the entire contents of the tube onto a glass plate coated with egg white, mixed and smeared the two fluids, and then let the preparation dry. Finally, the entire spread was counted with the aid of a finely squared (but not calibrated) micrometer that had been inserted into the ocular of the microscope. Overall, the procedure required at least three hours to complete and was quite tedious, but the results were surprisingly accurate, even by today's standards.[12]

Later that year, Vierordt published "Zählungen der Blutkörperchen des Menschen" (Blood Corpuscular Counts in Man), in which he describes his

self-experimentation with nine erythrocyte counts between October 6, 1851, and March 7, 1852. In the first trial he calculated his red count at 5,010,000 cells per cubic millimeter of blood. The average of the nine trials was 5,174,400 cells per cubic millimeter of blood. Vierordt subsequently modified his procedure by diluting the blood with gum arabic and preserving a small quantity of the mixture in a container so that he could make repeated counts from the same sample; but, overall, his work can be seen as the actual birth of efforts by a physician-scientist to quantify the number of red cells in a cubic millimeter of blood.[13]

Vierordt's pupil, Herman Welcker (1822–1897), improved the technique further in 1854 by ruling the floor of the flat glass slide on which the cells were deposited.[14] Eventually that method was superseded by one introduced by Dutch physiologist Antonj Cramer (1822–1855). In 1855, Cramer devised a procedure by which he diluted a sample of blood with a salt solution so as to make approximately a 1:225 dilution. He then transferred a small portion of the mixture to a chamber that was created by cementing parallel bands onto the long edges of a slide and then cementing another thin slide on top of them. In that way, a space was created that held a minute quantity of fluid. The device could be filled by capillary attraction, which was advantageous because the approach provided for a more uniform distribution of cells within the counting chamber.[15]

In addition to working with a known quantity of blood that was diluted with

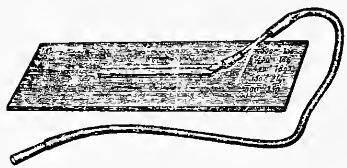


Figure 3. Malassez's capillaire artificiel.

a known quantity of salt solution and subsequently counted in a capillary space of known dimensions, Cramer used a squared ocular micrometer that was ruled into forty-eight oblongs to aid in cell counting. Whereas Vierordt's eyepiece was used only for orientation, Cramer's ocular was semi-calibrated. Cramer's blood-counting method met with moderate success, but unfortunately his early death prohibited him from refining the technique to the point where it would be able to win general acceptance within the scientific community. With the techniques of Vierordt, Welcker, and Cramer available, physicians and scientists could count red cells if they so desired, but it was not until the 1870s that the next significant step on the subject of cell counting was taken.[16]

Borrowing from the techniques of Vierordt and Cramer, in 1874 Louis-Charles Malassez (1842–1909), an associate director of the Histology Laboratory of the Collège de France and a pupil of Claude Bernard's, published a paper in which he described his *capillaire artificiel*, or counting capillary (Figure 3). Malassez's chamber consisted of a capillary tube that had been flattened or compressed so that it was elliptical in cross section. The capillary tube was then glued to a slide on which

there was a scale that equated the length of the column with the capacity of the tube.[17]

After a diluted sample of blood had been drawn into the capillary by means of the rubber tubing over the free end, a microscope equipped with a micrometric quadrilled ocular was placed over the tube, and the field of view was counted (Figure 4). Since the cubic contents of the tube were known, the number of red cells per cubic millimeter of blood could be readily determined by counting the number of cells in a given length of the tube and then applying the dilution factor.[18]

The next nineteenth-century physician-scientist to take up the study of cell-counting was Georges Hayem (1841–1933), a member of the Academy of Medicine. Hayem's 1875 cell-counting apparatus was formed by superimposing and cementing a 1/5-millimeter-thick glass plate with a one-centimeter-diameter hole cut out of its center upon a glass slide (Figure 5). With the aid of a spherometer (a device used to measure the curvature of curved surfaces and spheres), he could determine the thickness of the cavity with accuracy, and a trough of known dimensions would be created. The only significant drawback to Hayem's apparatus was that, unlike the capillary tubes of Malassez and the capillary cell of Cramer, his device could not be filled by capillary attraction. Instead, an unmeasured drop of blood that had been mixed with a preserving fluid—such as serum or the amniotic fluid of a cow—was delivered directly to the center of the cell and a cover glass was immediately applied. As a result of

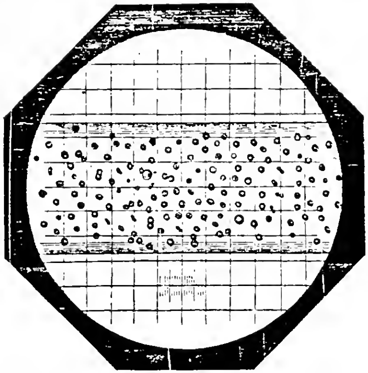


Figure 4. A view of the cells in Malassez's **capillaire artificiel** ***as seen through a microscope equipped with a micrometric quadrilled ocular.***

those manipulations, a thin sheet of liquid with parallel sides and of a known depth would be produced.[19]

Hayem equipped a microscope with a squared ocular micrometer, as introduced by Cramer, which he placed over the cells, and with that he was able to count the number of corpuscles within the field (Figure 6). Since each side of the large square was 1/5 millimeter in length, the counting space was equivalent to 1/125 cubic millimeters. In order to calculate the total number of cells in a cubic millimeter of blood, he multiplied the number in a square times 125 times the dilution factor.[20]

Hayem's *hématimètre* was manufactured by A. Nachet, located on the Rue Saint-Severin, Paris, and could be purchased through a catalog. Unfortunately, Hayem's method—as those of Vierordt, Cramer, and Malassez—failed to attract the attention of American or English physicians. His apparatus, like theirs, was arduous to apply and sometimes produced imprecise results. A

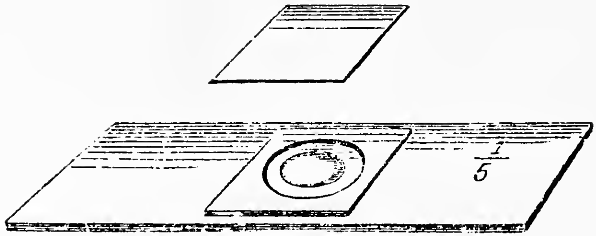
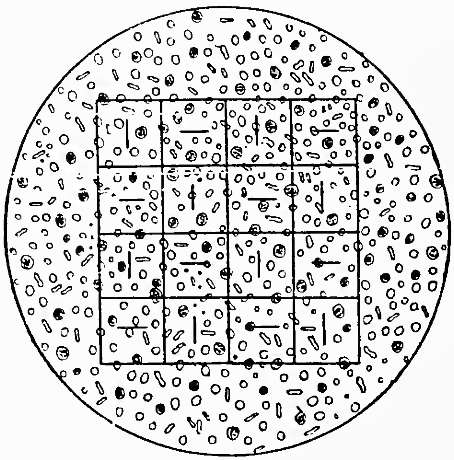


Figure 5. Hayem's apparatus for counting blood cells.

Figure 6. Field of view as seen through a microscope equipped with a squared ocular micrometer and focused on Hayem's counting chamber.



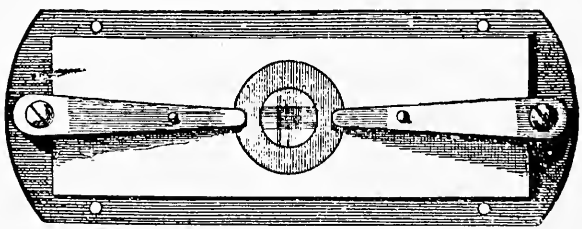


Figure 7. Gowers's counting chamber.

turning point in the history of blood counting occurred in 1877, when William Gowers (1845–1915), an assistant professor of clinical medicine in University College, published "On the Numeration of the Blood-Corpuscles" in the *Lancet*. Karl Bürker later noted that Gowers's blood-counting method created "a new epoch in blood counting."[21]

Gowers, who is remembered primarily as a neurologist, wrote that few observations on the "richness or poverty" of the blood had been made in England because (1) no instruments for that purpose had been developed in his native country, and (2) it was inconvenient to use instruments manufactured abroad (i.e., in Germany and France) because they could be used only with a given microscope that had been fitted with a quadrilled ocular specifically calibrated for that particular scope.[22] To overcome the inconvenience of using only one special microscope for every count, Gowers contracted with a Mr. Hawksley of 300 Oxford Street, London, to prepare a modification of Hayem's instrument.[23] Gowers's cell (Figure 7) was the first counting chamber in which the ruling was placed at the bottom of the slide.[24]

Gowers's cell (like Hayem's and Nachet's) was exactly 1/5 millimeter deep. Gowers's chamber, however, was divided into squares 1/10 millimeter in width and length. Also, the cover glass on his cell was kept in place by means of two springs rather than a viscous liquid (such as saliva) between the rim of the lumina and the cover glass. Since the dilution factor was two hundred, the number of cells in a cubic millimeter of blood could be found by counting ten squares and multiplying by ten thousand.[25]

In 1906, Gowers had the Messrs. Hawksley modify the apparatus by dividing the squares horizontally. The new parallelogram configuration must not have proven popular with clinicians, however, as it did not appear in trade catalogs of the day. Nevertheless, Gowers's place in the history of blood-counting techniques was assured when he abandoned the ocular micrometer in favor of ruling the floor of the counting chamber.[26]

The Thoma-Zeiss Counting Chamber

The next significant step in the technique of blood counting was taken in 1881, when Richard Thoma (1847–1923), an assistant at the Pathological Institute of the University of Heidelburg, published a paper in collaboration with J. F. Lyon, an American physician from Norwich, Connecticut, in which he described his counting chamber (Figure 8). Thoma's cell was made by the optical firm of Carl Zeiss and Company of Jena, and it consisted of a thick, evenly ground glass slide (*objektträger*) upon which a thin glass plate with a hole at its center had been cemented. A second plate was then cemented into the center of the trough so

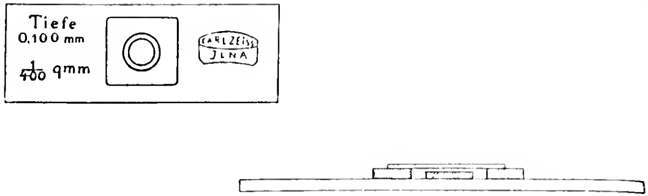


Figure 8. Thoma's counting chamber and a cross section of the instrument showing the raised platform.

as to create a bull's-eye configuration. Since the plate that formed the platform was surrounded by a moat 1/10 of a millimeter thinner than the main plate cemented to the *objektträger*, a space 1/10 millimeter deep was left when the cover glass was applied.[27]

At the center of the free surface of the platform, a one-square-millimeter area was divided into four hundred small squares (Figure 9). That area was further divided into sixteen sets of twenty-five squares (Figure 10). The number of erythrocytes per cubic millimeter of blood was expressed as the following equation: the number of cells counted times the cubic contents of each square and the degree of dilution and divided by the number of squares counted.[28]

Thoma's counting chamber was further improved upon in England by Hawksley, who modified it by molding the entire apparatus out of a solid piece of glass rather than from component parts that had been cemented together. Thoma's name became a household word in clinical laboratories in the first part of the twentieth century. The 1912 edition of James Campbell Todd's *Clinical Diagnosis* notes that "the most widely used and most satisfactory instrument for counting the corpuscle is that of Thoma-Zeiss."[29]

At about the same time that Thoma was perfecting his blood-counting apparatus, Malassez introduced a second device for counting corpuscles that featured what he termed a *chambre humide graduée*. Basically, the instrument consisted of a slide in the middle of which sat an "island" surrounded by a groove or "ditch." After a drop of the diluted blood had been deposited on the rectangularly graduated central circle, a cover glass was positioned on top of the tips of three or four screws that had pierced the glass from the underside and whose height could be calculated, and a drop of water was added to the outside edge of the groove so as to prevent evaporation. A *compresseur*, or hinged carrier, was used to keep the cover glass in position on the screws, and then the cells were counted and the usual calculations were made to determine the number of cells in a cubic millimeter of blood. Malassez's instrument was available through the catalog of the manufacturer, M. Staissnie, Boulevard Raspail 204, Paris, and essentially it resembled the moated counting chamber of Thoma.[30]

In 1884, Sergi Alferow, a Russian working in Paris, recognized the fact that it was sometimes difficult to obtain valid counts with the hemocytometer because of either faulty construction or the lack of a uniform distribution of corpuscles within the counting chamber. Alferow sought to overcome the problem by designing his own chamber. His apparatus was formed by isolating the counting platform from the rest of the slide by means of two parallel troughs (Figure 11). The depth of the chamber was controlled by resting the cover glass on four micrometer screws or small colored glass tubes of known height, which were fitted into holes that had been specially bored for them. With the cover glass resting on the pillars, it was secured in place by two clamps, one on each side,

Figure 9. Thoma's ruling or netting that was etched into the surface of the platform.

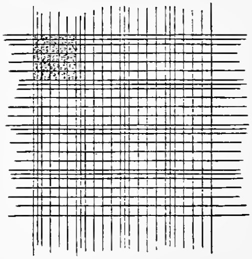


Figure 10. Close-up of Thoma's ruling showing red corpuscles in the upper-left- hand corner.

and then the cell could be filled by capillary attraction using the principles laid down in 1855 by Cramer.[31]

To count the cells, Alferow either took a microphotograph of the corpuscles or projected their images onto a glass disc divided into squares and then marked their position on the disc with a pencil. Although his procedure was more time consuming than conventional counting methods, Alferow considered it more accurate because it created a permanent record of the exact number of cells present in the chamber.[32]

A novel apparatus for counting cells was introduced in 1903 by W. Brünings of the Pathological Institute of the University of Zürich (Figure 12). Brünings's device consisted of a counting field engraved on a flat wall in the lumen, a mixing pipette, and a suction portion that contained a second mixing chamber. The instrument was originally designed to surmount any errors that might result from the faulty transfer of the diluted blood in a separate mixing pipette to the counting chamber. Brünings solved the problem by simply incorporating the counting chamber and mixing pipettes into the same instrument.[33]

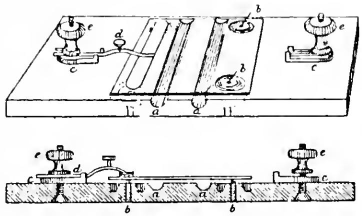


Figure 11. Alferow's counting chamber.

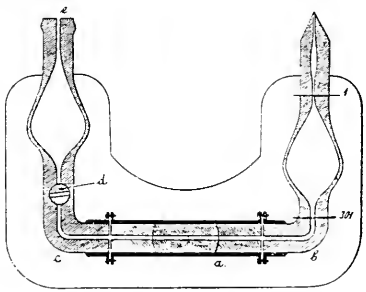


Figure 12. Brünings's instrument for cell counting.

The Bürker Counting Chamber

Of all the scientists and physiologists that have been mentioned so far, none surpass the ingenuity of Professor Doctor Karl Bürker (1872–1957) in bringing the process of blood counting to new heights of accuracy. In a series of papers published between 1905 and 1913, Bürker of the Pathological Institute, Tübingen, described the development of his hemocytometer. It was the Bürker counting chamber, with its subsequent modifications, that eventually superseded the closed or Thoma-Zeiss counting chamber and other competing devices.[34]

Bürker's chamber (Figures 13 and 14) was made from a heavy ground-glass plate or slide upon which was cemented three narrow parallel platforms. The first platform, or "floor piece," was formed from a piece of glass twenty-five millimeters long and five millimeters wide with rounded ends that were divided into parts by means of a ditch 1.5 millimeters deep. The second and third

platforms were twenty-one millimeters long and 7.5 millimeters wide; they were separated from the floor piece by a channel 1.5 millimeters wide. The second and third platforms were cut so that a space 0.1 millimeters deep was formed when a cover glass was laid across the top of the cell and secured with cover glass clamps.[35]

Bürker's "double counting chamber" was the culmination of all the effort that had been put into the process of perfecting a counting chamber. Not only could the cell be filled by capillary attraction, but with two ruled areas of one square millimeter subdivided into four hundred small squares, the operator could perform duplicate counts from the same sample of blood without having to re-clean and recharge his equipment. Bürker's invention was the prototype for subsequent models, and by 1921, Horace Gray could proclaim that "the best cell-counting chamber is generally considered to be the 'double Bürker.'"[36]

In summary, the early pioneers who developed the hemocytometer counting chamber were physician-academics—Vierordt, Thoma, Brünings, and Bürker in Germany, Malassez and Hayem in France, and Gowers in England. Their initial impetus for developing each instrument had been to study the physiology of the red cell. Later, the emphasis switched to using the hemocytometer counting chamber to diagnose disease states. The instrument itself evolved through a series of stages that ranged from counting all the cells on a slide to enumerating the number of corpuscles on a grid.

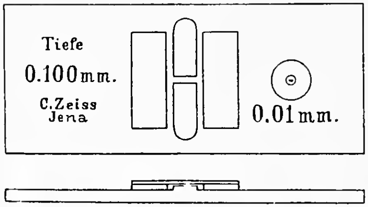


Figure 13. Bürker's counting chamber with cross section of the device shown.

Figure 14. Bürker's counting chamber from a photograph.

Ideals of the Progressive Age

The most definitive refinements of the hemocytometer coincided with the Progressive Era (roughly the first two decades of the twentieth century), during which scientific advances in the fields of microscopy, chemistry, serology, and hematology helped physicians identify both the causes and effects of various disease processes upon mankind. Between 1852 and 1920, the hemocytometer counting chamber was modified by several ingenious individuals, but the basic technique remained the same. A diluted sample of blood was placed within a chamber of known dimensions, the numbers of cells in a given area were counted with aid of a microscope and a grid, and a mathematical formula was applied that gave the final answer in terms of the number of cells

per cubic millimeter of blood. In the years that separated Vierordt from Bürker, the physician's knowledge of the causes of disease had increased, and the hemocytometer counting chamber was instrumental in bringing about that change.

Building on the insights of Louis Pasteur (1822–1895) and Robert Koch (1843–1910), American scientists and physicians in the early 1900s were able to isolate, identify, and roughly quantify bacterial entities that gave rise to such diseases as diphtheria, typhoid, and streptococcal and staphylococcal infections. In the field of chemistry, the American scientist Stanley Rossiter Benedict (1884–1936) developed a test for sugar in the urine in 1907 that helped the physician gauge the severity of a patient's diabetic condition. Similarly, August von Wasserman (1866–1925) pioneered a test for syphilis that eventually led to early detection of that venereal disease in the general public. And finally, in 1901, John Scott Haldane (1860–1936) published an article in which he described an instrument that could be used to measure the hemoglobin content of the blood. In short, Progressive-Era medicine, at least from a laboratory perspective, was characterized by an emphasis upon quantification. The physician's growing ability to identify and enumerate various biological and chemical markers of disease was one of the medical hallmarks of the age, and the hemocytometer was one of the most visible embodiments of that ability.

Parallel to refinements in the counting chamber were a number of innovations in other accoutrements that contributed to the overall accuracy of the hemocytometer system. They also emerged from the general impulse to identify, measure, and quantify.

Pipettes, Diluting Fluids, and Counting Nets

While the development of the counting chamber was of singular importance, the system could not function without the aid of auxiliary pieces of equipment. Pipettes were needed to make accurate dilutions of blood and preserving fluids. The fluids had to preserve the integrity of the cellular material that was to be enumerated. Cells could not be accurately assessed if they were not displayed upon an accurately calibrated counting grid. The evolution of pipettes, diluting fluids, and counting nets contributed enormously to the overall efficiency and accuracy of the counting chamber.

In his initial mid-nineteenth-century efforts to perform blood counts, Vierordt used a capillary that was calibrated in diameter but not in length. Welcker introduced a pipette holding a fixed volume of fluid that was readable to the naked eye in 1854. Cramer used two pipettes in his work—one to transport the salt solution to a flask, and one (a capillary pipette) to transfer the blood to the same flask for mixing. All three clinicians used separate pipettes for each manipulation of the blood and diluting solution.[37]

In 1867, Pierre-Carl-Edouard Potain (1825–1901), an associate of Malassez's, invented his *mélangeur*, or diluting pipette (Figure 15), which became the

Figure 15. Potain's mélangeur.

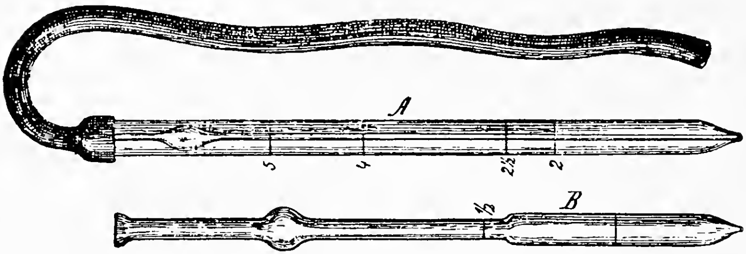


Figure 16. Hayem and Nachet's pipette system.

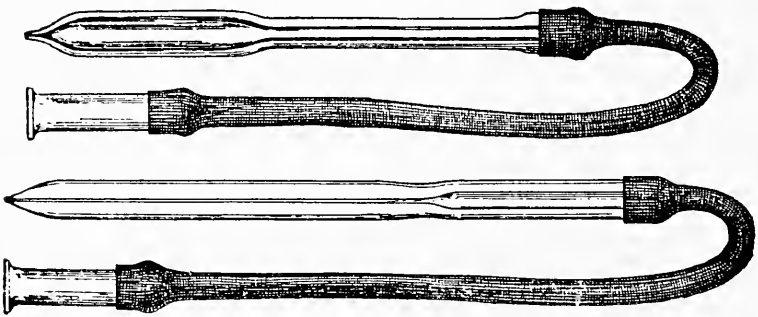


Figure 17. Gowers's pipettes.

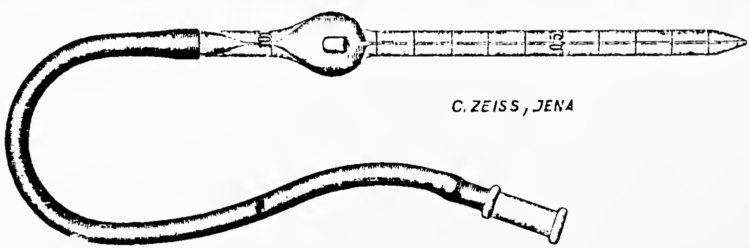


Figure 18. Thoma's pipette.

prototype for the erythrocyte (or red cell) pipette used in hematology laboratories even today. Potain's pipette allowed the operator to not only measure the cellular fluid and the diluting solution but to mix them together in an ampulla that was an integral part of the *mélangeur* itself. Malassez found the pipette to be indispensable and used it with his *capillaire artificiel*.[38]

The systems of Hayem and Nachet (Figure 16) and Gowers (Figure 17) used separate pipettes to hold the blood and the diluting solution before the contents of the tubes were delivered to a small glass jar or test tube for mixing.[39] In 1879, Thoma enlarged the bore of the *mélangeur* (Figure 18) to facilitate cleaning, adjusted the length of the pipette to eight centimeters, and increased the size of the ampulla so that it could hold one cubic centimeter of fluid. Thoma's pipette was so accurately calibrated by Zeiss that it quickly overshadowed the pipette systems of Gowers and Hayem and Nachet, earning a place of preeminence among the users of single-mixing pipettes. In 1882 Thoma created a leucocyte (or white cell) pipette that was capable of attaining a 1:10 dilution, and by the early 1920s, the most popular and accurate was the Thoma-Zeiss version of the Potain-Malassez *mélangeur*.[40]

As a direct result of the work done by Potain and Thoma, separate *mélangeurs* were developed for counting red and white cells. The red pipette, whose ampulla was capable of holding one cubic centimeter of fluid, was used to make the 1:100 or the 1:200 dilutions that were customarily made when erythrocytes were to be counted. The white cell pipette was ordinarily used to make dilutions of 1:10 or 1:20, and its ampulla consequently held only one tenth of a cubic centimeter of fluid. Both types of pipettes were manufactured by a variety of European firms, including Zeiss, Richert, and Leitz.

The number of solutions created to preserve and dilute red cells in the counting chamber was quite large. Essentially, any isotonic salt solution could be used; indeed, Hayem and Nachet went so far as to suggest using "the liquid of the amniotic cavity of the cow, and above all, the serosity of the dropsical effusions that occur in the human subject in certain pathological cases."[41] Occasionally, aniline dyes were added to the solution to stain the component parts of the blood, but the choice of what solution to use more often depended the individual preferences of the operator.[42]

The most popular solutions for blood counting in the early 1900s were Hayem's solution (mercuric chloride, sodium chloride, sodium sulphate, and distilled water), Gowers's solution (an aqueous, or water, solution of sodium sulphate with a specific gravity of 1.025), and Toisson's solution (Methyl-violet, 5B, sodium chloride, sodium sulphate, neutral glycerine, and distilled water). Toisson's fluid was suggested for beginners because its high degree of coloration made it easy to detect when drawn into the pipette, but Hayem's solution was the overall favorite for red cell counting because of its ability to preserve cells without distorting them. Other solutions were offered by Potain's solution, Pacini's solution, Mosso's solution, Mayet's

solution, Löwit's solution, Sherrington's solution, and Edington'solution.[42]

With all the exotic recipes abounding for counting red cells, it is interesting to note that the simplest and most widely used solution for counting white cells was a five-percent solution of glacial acetic acid, which both dissolved the erythrocytes and enhanced the appearance of the leucocytes at the same time.[43]

Originally laid out by Thoma in 1879, the "Thoma cross" was a classic gridiron ruling. Toward the end of the century, however, it was realized that the Thoma cross was not suitable for white counts. Among workers modifying the rulings, J. Zappert in 1892 drew a recessed line across each of the four ends and thus enclosed an area of nine square millimeters (Figure 19).[44] Two years later, A. Elzholz added three pairs of vertical lines through the left and right column (Figure 20); W. Türk in 1902 added three pairs of horizontal lines to Elzholz's design (Figure 21), and that configuration largely displaced Thoma's original net. Around 1907, O. Neubauer used single, rather than double, dividing lines for a new ruling scheme (Figure 22), which greatly enhanced the clarity of the overall design of the counting grid. As a result of simplifying the grid pattern, the Neubauer ruling displaced Türk's; by the early 1920s the Neubauer had become the most popular style of ruling.[45]

When the counting chamber, the pipettes, the diluting fluids, and the grids were all combined into a functional unit, a technological device was created that provided the Progressive-Era physician with valuable information about the patient's physical condition.

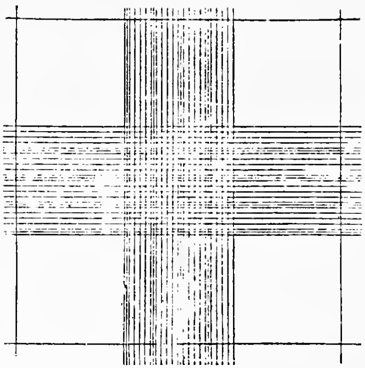


Figure 19. Zappert's ruling.

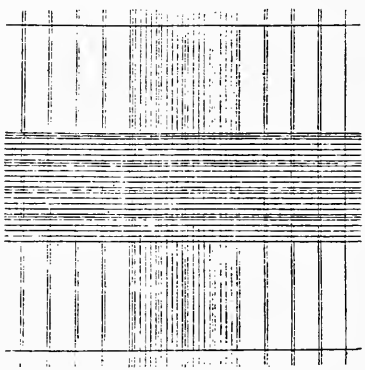


Figure 20. Elzholz's ruling.

Conclusion

The hemocytometer was initially created for the purpose of aiding physicians-scientists in their quest for a basic understanding of the physiological properties of red cells. Over time, repre-

sentatives of the medical community realized that the instrument could be adapted to their discipline. Many noteworthy physicians worked on the problem of how to best utilize the instrument in the practice of medicine. The end product of their labors was a plethora of different styles of counting chambers, pipettes, diluting fluids, and counting grids. In 1880, Dr. Joseph W. Hunt of London penned a most telling comment about the transition of the hemocytometer from an experimental tool to a practical diagnostic device. He wrote in the *Lancet* that "though at first I was struck by what I considered to be the inefficiency of the haemacytometer and the haemoglobinometer, and regarded them merely as scientific toys, a more extended use has fully persuaded me of their great value."[46] Overall, Hunt was quite correct in his evaluation of the instrument.

With the advent of the hemocytometer, the physician was able to establish a correlation between the patient's outward physical symptoms and a quantitative determination of the number of cells that were actually contained within a measured amount of blood. The ability to "look within" the patient enabled the physician to detect such red cell diseases as chlorosis, pernicious anemia, leukemia, and polycythemia. Likewise, surgeons acquired the ability to assess white counts in anticipation of surgery for appendicitis, cholecystitis, and abscesses.

As information about the instrument and its diagnostic capabilities was disseminated by means of the immigration of foreign physicians, native-born physicians returning home after postgraduate work in Europe, trade catalogs, journal articles, and textbooks, physicians began to order more blood work on their patients. Blood counts were assimilated into hospital laboratory procedures, a fact that attests to the importance of the hemocytometer to medical progress.

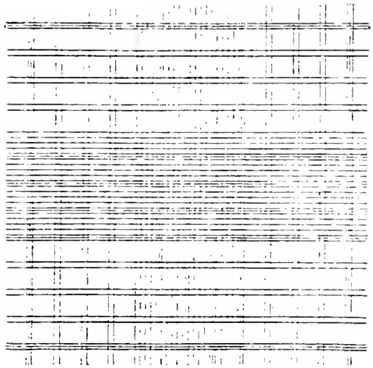


Figure 21. Türk's ruling.

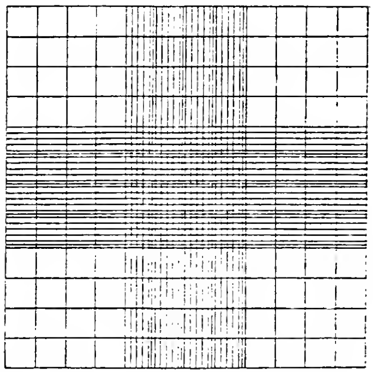


Figure 22. Neubauer's ruling.

Conceived in Europe, brought to American shores, and eventually totally absorbed into American practice, the hemocytometer grew to maturity between the two world wars, and was only partially retired with the dawn of the "electronic age" after World War II. By providing the physician with a way to evaluate quantitively a patient's condition, it helped to standardize medical practice in the twentieth century.

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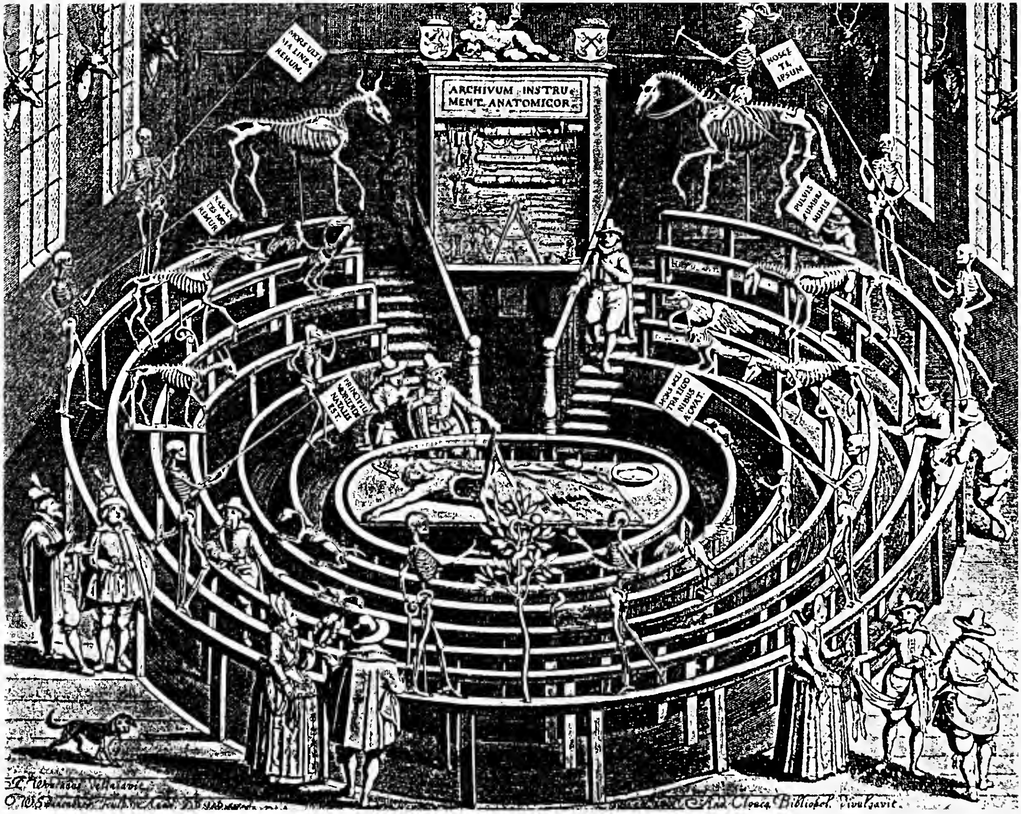

The Anatomical Theater at Leiden, 1610

Anatomical Comparisons, Metaphysical Conceits: Poets, Physicians, and the Motions of the Heart

Invention, Nature's child, fled step-dame Studie's blowes,
And others' feete still seem'd but strangers in my way.
Thus great with child to speake, and helpless in my throwes,
Biting my trewand pen, beating my selfe for spite,
"Foole," said my Muse to me, "looke in thy heart and write."

Philip Sidney, *Astrophil and Stella*[1]

The heart. Renaissance poets rarely mention love without mentioning the heart. Still it is doubtful that Philip Sidney, who wrote the lines above between 1581 and 1583, was concerned about the new understanding of the heart emerging from the work of continental anatomists Andrea Cesalpino, Realdo Columbus, or Fabricius of Aquapendente. Yet Sidney's lines echo events on the continent by commanding the poet to look directly into his heart rather than into books, thus presaging the career of the greatest heart specialist of England's next generation—William Harvey.

Born on the first of April in 1578 in Folkestone, Kent, Harvey certainly came to share Sidney's scorn of Galen's "adoptive sonnes, who by a beaten way / Their judgements hackney on."[2] From his graduation from Cambridge until 1602, Harvey studied principally at Padua, where Vesalius—artist, rebel, exploiter of the printing press—had fled "step-dame Studie's blowes," "invented" (discovered) new aspects of the body unwritten in the works of Galen and Aristotle, and "invented" (created) an array of new instruments. There, in the candle-lit, oak-lined anatomical theater, Harvey heard the lectures of Vesalius's successor Fabricius.

Such parallels as may exist between the work of Sidney and those of the continental anatomists appear trivial. Yet I will argue that by examining the work of Harvey and the changing paradigms of English poetry we can find a relationship between the scientific and poetic

by David Rosen

communities of early modern England, their practices, and their material conditions. I will argue that the two communities shared a discourse that embeds similar underlying assumptions that fostered a new, common direction. Discourse, a precondition of discovery, was being radically reshaped by poets. Understanding that discourse is helpful in understanding how Harvey discovered the circulation of the blood.[3]

Many would maintain that no possibility for poetry to contribute to science exists, particularly in the Renaissance.[4] In *De Studio Medico,* the Renaissance physician Caspar Bartholin rejects the relevance of rhetoric to physic—"not words but herbs effect the cure."[5] So agrees the 1577 epigraph to *A Profitable Treatise of the Anatomie of Mans Body:*

> Nowe he that is the perfect guyde,
> doth knowe our helpes were here alone.
> By homely style it may be spyde,
> for rules in Rethorike haue we none:
> Our heads doo lacke that syled phrase,
> whereon fine witte delight to gase.[6]

The collectors of Vicary's anatomy suggest that while wits look at words, physicians view real bodies. Yet the physician's "homely style" testifies to the *importance* rather than the unimportance of words. A particular rhetoric was deemed appropriate for the discourse of science.

In writing about bodies, a Renaissance physician rarely stuck to homely discourse. Vicary himself used metaphor, even Biblical metaphor. "Surgeons that work in man's body not knowing the Anatomy," wrote Vicary, should be "likened to a blind man that cutteth in a vine tree, for he taketh more or less than he ought to do."[7] When Francis Bacon inaugurates, *Instauratio Magna,* published in 1620, by claiming that his scientific study of the world would be "unencumbered by literature and book-learning," he thereby repeated the literary gesture of Sidney's first sonnet.[8]

The importance of the poet, whether philosopher or rhetorician, is suggested by Harvey in an "NB" addendum to his *Prelectiones Anatomiae Universalis:* "Galen was not discoverer of nerves from brain to senses. Cicero, Tusculanian Disputations, I p. 339. Likewise Cicero [has] much [to say] about the use of the parts in De Natura Deorum, book 2."[9] One would have a difficult time arguing that Cicero deserves the credit for Galen's discoveries; on the other hand, Harvey's willingness to entertain a "poet" as the author of scientific discoveries suggests his own sense of influence. One must, then, dissent from Charles B. Schmitt's claim that "[w]hatever use, or pretended use, rhetoric may have had in renaissance history writing, politics, or royal ceremonial, it could claim little direct relevance for medicine or the sciences other than in the purely propagandistic role to which figures such as Bacon or Galilei turned it."[10]

Paradigm Shift in Poetry

In his *Miscellany,* published first in June 1557 and twice more that year and subsequently each decade until 1587, the printer Richard Tottel collected the works of not only Henry Howard, Earl of Surrey but also Sir Thomas Wyatt the

Elder, Nicholas Grimmald, Sir John Cheke, John Heywood, Thomas Norton, and other intellectual and poetic luminaries of the period. That influential collection had for Tottel a clear polemical purpose. According to the preface, he had published for the "honor of the Englishe tong, and for profit of the studious of Englishe eloquence . . . . And I exhort the vnlearned, by reding to learne to be more skilful, and to purge that swinelike grosenese."[11] That is, the volume announced itself to be resolutely new, for it promised to establish English as a language equal in beauty to that of other European countries that had produced highly acclaimed vernacular verse. At the same time the volume proposed to refine the English tongue by publishing poems that copied and frequently translated continental poets, in particular Petrarch. For educated Englishmen coming of age under Elizabeth, the volume would serve as a model for vernacular literature. It also gives a clear picture of the common cultural understanding being fashioned at the time.

From the opening poem on, "Descripcion of the restlesse state of a louer, with sute to his ladie, to rue on his diyng hart," the volume takes great interest in the heart. Most references, of course, bear little relationship to any known physical facts about the organ, as these pages indicate: "I asked but my ladies / To haue for euermore myne owne" (61); "Svffised not (madame) that you did teare / My wofull hart" (74); "Svch grene to me as you haue sent, / Such grene to you I sende agayn: / A flowring hart that wyll not feint" (179). The heart can be steadfast, fickle or dissembling. As the site of the lover's feelings, the heart becomes a metaphor rather than a part of the real operation of the body:

> The dolefull bell that still dothe ring,
> The wofule knell of all my joyes:
> The wretched hart dothe perce and
>   wringe,
> And fils mine eare with deadly noyes.
> The hungry vyper in my brest,
> That on my hart dothe lye and gnawe:
>
> . . . .
>
> Yet goeth the mill within my hart,
> Which gryndeth nought but paine and
>   wo:
> And turneth all my joye to smart,
> The euil corne to yeldeth so.

The images of the heart lack elementary physiological details that either experience or study might have taught the poet. For instance, the poet does not compare the heart to a tolling bell that knocks against his chest. The tolling bell instead "doth perce and wringe"; a viper gnaws it like Eve's apple, and it houses a grindstone.

Yet much of the verse in *Tottel's Miscellany* also reflects both the symptomology of love and an accepted idea of physiology. For instance, in the opening poem, Henry Howard, Earl of Surrey borrows images that reflect current theories on the workings of the heart. Although many of the images and lines were adapted from Petrarchan sources,[12] they could not have been employed without a requisite understanding of the body:

> since I haue hid vnder my brest the harm
> That neuer shall recouer healthfulnesse.
> the winters hurt recouers with the warm:
> The parched grene restored is with
>   shade.

> What warmth (alas) may serue for to disarm
> The frosen hart that mine in flame hath made?
> What colde againe is able to restore
> My fresh grene yeares, that wither thus and fade?

According to Galenic medicine, the human body was divided into three parts—abdomen, chest, skull—each a major cavity dominated by a major organ—liver, heart, brain. The central heart divided the body in half. Excretion lay below, intake above. The heart also produced animal spirits that heated the body. The lungs in turn acted as a bellows to blow on the fire and to cool spirit that was too hot. Moreover, the lungs acted as an exhaust system that rid the body of noxious fumes from the fire.[13]

Warmth was the central principle of life, and heat was associated with love. In particular, however, because men were hot and women were cool, the love of a woman could moderate the heated man. On the other hand, rejection by the beloved could produce too much cooling, as in the poem "The complaint of a hot woer, delayed with doutfull cold answers." The movement of the blood was also connected with hot and cold. A part of the body deprived of blood became cold, a part with a surplus of blood burned.

We can see the physiology of the lover, the blood, the heart, hot and cold, put together in Surrey's translation of the Petrarchan sonnet *Amor, che nel penser mio vive et regna:*

> Loue, that liueth, and reigneth in my thought,
> That built his seat within my captiue brest,
> Clad in the armse, wherin with me he fought,
> Oft in my face he doth his banner rest.
> She, that me taught to loue, and suffer payne,
> My doutfull hope, and eke my hote desyre,
> With shamefast cloke to shadowe, and refraine,
> Her smilyng grace conuerteth straight to yre.
> And coward Loue then to the hart apace
> Taketh his flight, whereas he lurkes, and plaines
> His purpose lost, and dare not shewe his face.
> For my lordes gilt thus faultlesse byde I paynes.
> Yet from my lorde shall not my foote remoue.
> Swete is his death, that takes his end by loue.[14]

Although warfare seems to be the main metaphor, what determines the action of warrior Love is his identification with the blood. Without permission of the lover—the heart does not act through will but by nature—the heat of desire causes blood to suffuse the face, while shame makes the hot blood retreat to the heart, where the excess heat is dispelled by "plaints."

The physical operation of the hot blood, heated further by desire, and the cooling by suffusion or exhalation—blushing, sighing, singing—becomes the common symptomology of love for the poets of mid-century. In such lines as "When euery loke these chekes might staine, / From deadly pale to glowing red: / By outwarde signes appered plaine, / The

woe wherin my hart was fed," the images become symptoms of the activities of the heart, an etiology of the uncertainty of love and the strain put on the moderation of body heat: "Anone the bloud start in my face agayne, / Inflamde with heat, that it had at my hart. / And brought therwith through out in every vaine, / A quakyng heat with pleasant smart." So "smoky sighes, that ouercast the ayer" break forth from the overcharged breast and the blood's heat converts from "panges of plaint to fits of fume. / . . . Yet haue I felt full oft the hottest of his fire: / The bitter teares, the scalding sighes, the burning hot desyre. / And with a sodain sight the trembling hart: / And how the blood doth come, and go, to succour euery part." Thus the physiology of the heart structures much of the love complaint that composes the greatest bulk in *Tottel's Miscellany*.

The ever-presence of the anatomist's physiology in the complaints of love poets suggests that a common cultural understanding of the body existed, that the importance of heat, blood, heart, respiration—their interaction and consequence for health—could be taken for granted by both poet and physician. Only in such a context can we appreciate the significance of Sidney's simultaneous rejection of the physiological and poetic apparatuses:

> Because I breathe not love to everie one,
> Nor do not use set colours for to weare,
> Nor nourish speciall lockes of vowed
> haire,
> Nor give each speech a full point of a
> grone,
> The courtly Nymphs, acquainted with
> the mone
> Of them, who in their lips *Love's*
> standerd beare;
> "What he?" say they of me, "now I dare
> sweare,
> He cannot love: no, no, let him alone."[15]

Writing thirty or forty years after the *Tottel* poets, Sidney owed those poets a great debt for their refinement of the English language. On the other hand, Sidney sought to free English from its foreign servitude. In part, that meant doing away with the older gestures and languages of love. But it also meant revisiting the structuring ideas behind language. Sidney and the poets of his generation were not really revolutionaries against Galenic thought, despite his sonnet 102 of *Astrophil and Stella* to the contrary. But in fashioning new tropes, they distorted or destroyed the Galenic physiology that underlay the old ones. In fact, the new general structure of figurative language was antithetical to the structures on which Galenic ideas depended. A comparison of the *Tottel* poets to Sidney will make clear some startling differences in starting presuppositions.

Antithesis dominates the earlier poetry. A common organization of Tottel's collection is verses on a theme followed by answering verses; a common theme is steadfastness versus change. So in *Tottel,* when "The lover lamenteth others to haue the frutes of his seruice," he writes completely in contraries:

> I fast, they fede: they drynke, I thurst.
> They laugh, I wayle: they ioye, I mourne.
> They gayne, I lose: I have the worst.
> They whole, I sicke: they cold, I burne.[16]

That antithesis has a power to structure and even influence other ideas, including change, motion, and the circle—all important aspects of the contemporary and changing conception of the body. In "The louer for want of his desyre, sheweth his death at hand," for example, the poem builds through a series of antitheses:

As Cypres tree that rent is by the roote.
As branch or slyppe bereft from whence it growes
As well sowen seede for drought that can not sprоute
As gaping ground the raineles can not close
. . . .
As salamandra repulsed from the fyre:
So wanting my wishe I dye for my desyre.

Thinking antithetically thus makes "change," valued negatively, the antithesis of "steadfastness" and "faith": "As nothing can endure, / That liues and lackes reliefe, / So nothing can stande sure, / Where chaunge dothe raigne as chiefe." Thus change can only be seen as a corrosive, an inconstant.

That type of binarism affected even what was then and would remain the singlemost important image for the heart: the circle. In all 310 poems of Tottel's anthology, the image of the circle, stated or implied, appears perhaps fewer than a dozen times. When it does appear, such as in "Of Fortune, and Fame," the structuring principle is the machinery of a mill, not of a merry-go-round. The principle direction of force is up and down, not round and round. The person on the wheel rises and falls: "fortune lifted after this, / And set me hye vpon her whele: / And changed my wo to pleasant blisse, / And so the sodeyn fall agayne / From all the ioyes, that I was in." The antithesis of up and down is more fully elaborated in "Of Fortune, and Fame," where the author describes those "That subiect are to fortunes whele":

Her happy chance may last no time:
Her pleasure threatneth paines to come.
She is the fall of those, that clime:
And yet her whele advanceth some.
No force, where that she hates, or loues:
Her ficle minde so oft remoues.

The motion of the wheel and its effects are ranged in opposed pairs: pleasure / pain; climb / fall; love / hate; advance.

The structure of the verse deprives the circles of circularity, of circulation. The poets even conceive the circle of the sun as a binary movement: "From East to West, from West to East so doth his journey ly."

The poetry's important structuring principle of the straight line—with its polar opposites, its "gold mean," and its immoderate changeableness—is congruent with the physiological lore that underwrites the pathology of love: the body must moderate hot and cold, the arterial and venal bloods travel in straight lines from the heart or liver, moving up and down the body heating and cooling.

Sidney breaks from the structures of these earlier songs. From 1577 to 1581, as Sidney experimented with verse forms and perfected his craft, he rejected the Petrarchan and Chaucerian forms inherited from Tottel's volume, especially

the tropes associated with the pathology and symptomology of love:

> My hand doth not here witnesse with
> my hart,
> She saith, because I make no wofull
> laies,
> To paint my living death, and endlesse
> smart:
> And so for one that felt god *Cupid's* dart,
> She thinks I leade and live too merrie
> daies.
> Are *Poets* then the onely lovers true,
> Whose hearts are set on measuring a
> verse:
> Who thinke themselves well blest, if
> they renew
> Some good old dumpe, that *Chaucer's*
> mistresse knew,
> And use but you for matters to
> rehearse?[17]

That poem, from an early group in *Certain Sonnets*, clearly aimed at Tottel who had published a poem by Chaucer in his anthology and whose poets emulated the English master almost as much as the Italian one. Sidney's poem rejects the outward signs of pain and living death, the "good old dump," as affectation.[18] That rejection simultaneously dismisses the past poetic and diagnostic practices of the poet-physicians.

Sidney's later sequence, *Astrophil and Stella*, forcefully claims his bold departure, from its first innovative twelve-syllable line to its repeated repudiation of Renaissance matter and method. The poems dispute the love-at-first-sight convention and the notable absence of physical desire from love descriptions. In sonnet 3 the poet scorns writers who imitate classical style and embellish their plain subjects. For Sidney the imitation of nature is the true calling of the true poet: "all my deed / But Copying is, what in her Nature writes."[19]

The subjects and images of Sidney's poems, in fact, exhibit a striking concentration on observation. One group of early poems bears the title "These foure following Sonnets were made when his Ladie had paine in her face."[20] In *Astrophil and Stella* the poet's eye picks out what lies in the world around him: "wood-globes of glistring skies" and cheap "Indian ware"; contemporary child-rearing practices: "Sweet babes must babies have, but shrewd gyrles must be beat'n"; the sturdy beggars that troubled the Elizabethan countryside. He also alludes to international events—"Whether the Turkish new-moone minded be / To fill his hornes this yeare on Christian coast"—and particularly to the new world.[21]

But Sidney does not rid himself of all the baggage of the previous generation. *Astrophil and Stella* in particular abounds in mentions of the heart. In many, the heart is hot. In some the lover cools. In others the heat of the heart gives rise to singing. But even more often the heart is a place of introspection, something to be examined, and the mind very often replaces the heart as the site of amatory drama.[22] Nor do antitheses and binarism disappear from Sidney's love poems. Yet often antithesis has been transformed in a new and interesting way. For instance, sonet 76 of *Astrophil and Stella* begins with a familiar contrast: "She comes, and streight therewith her shining twins do move / Their rayes to me, who in her tedious

absence lay / Benighted in cold wo, but now appeares my day, The onely light of joy, the only warmth of *Love.*" The poem continues, however, to play with her sunlike warmth and the different times of day: at first she is gentle morning sun; then, having looked at the lover longer, she becomes hot noon sun. Finally the poet closes by wondering how warm her beams are in bed. The gradations in the poem toy with binarism in a way that transmutes the antithesis into something more complex.[23] Sidney demonstrates the ability to take a simple contrast and wring complexity from it in sonnet 91, which begins like sonnet 76:

> *Stella*, while now by honour's cruele
> might,
> I am from you, light of my life, mis-led,
> And that faire you my Sunne, thus
> overspred
> With absence' Vaile, I live in Sorowe's
> night.

However, it continues in a surprising manner:

> If this darke place yet shew like candle
> light,
> Some beautie's peece, as amber colourd
> hed,
> Milke hands, rose cheeks, or lips more
> sweet, more red,
> Of seeing jets, blacke, but in blacknesse
> bright.

Sidney escapes the binarism of black and white, night and day, by finding another light, candlelight. The description reminds one of Caravaggio, the late-sixteenth-century tenebrist whose strong light from a single source picked out vividly colored details. Like Sidney, he broke away from the rhetoric of contemporary painting to try to find a more naturalistic way of telling many of the old stories—the life of Christ, the classical myths.

Thus, while much of the old rhetoric may seem to structure Sidney's verse, a radical shift has occurred. While the heat of love still underlies many of Sidney's works, one can note subtle twists, as in 21 of *Certain Sonnets,* where desire seems to but does not immolate the lover. The poem actually concerns the attractive power of heat and desire, the ability of a force acting at a distance to shape movement. The idea and image of force operating at a distance, often associated with royal power, is one of the most frequent in Sidney's works:

> There shall he find all vices' overthrow,
> Not by rude force, by sweetest
> soveraigntie
> Of reason, from whose light those
> night-birds flie;
> That inward sun in thine eyes shineth so.
> And not content to be Perfection's heire
> Thy selfe, doest strive all minds that way
> to move,
> Who marke in thee what is in thee most
> faire.
> So while thy beautie drawes the heart to
> love,
> As fast thy Vertue bends that love to
> good.[24]

The force found in the action of the sun, of lodestones, and of touch recurs throughout the verses: "Of touch they are that without touch doth touch" or "*Stella* soveraigne of my joy / . . . *Stella* starre of heavenly fier, / *Stella* loadstar of desier."[25] The notion of force acting at a distance structures the verse of Sidney in

an age when his contemporary William Gilbert, a member of the College of Physicians in 1576, was to write and publish *De Magnete*, the immensely popular 1600 tract on the attractive power of the earth.

Two other characteristics are relevant to the paradigm shift from the earlier verse. One is the plenitude of comparison, which has the effect of mitigating antithesis. Not only does the poet draw comparisons from near as well as far, humble as well as celestial, observation as well as study, but the poet also seems compelled to find as many affinities or comparisons as possible. Certainly, such display is already apparent in the Tottel poets, but it is even more strikingly true here: "The scourge of life, and death's extrame disgrace, / the smoke of hell, the monster called paine."[26]

The other feature, which goes along with the breakdown of antithesis as the main structure, is the advent of the circle. Sidney's *Certain Sonnets* 21 illustrates circularity in that it expresses movement through four points: far to near and up to down. The circle is even more clearly present in sonnet 25:

> Turned anew by your meanse,
> Unto the flowre that ay turnes,
> As you, alas, my Sunne bends;
> Thus do I fall to rise thus,
> Thus do I dye to live thus,
> Changed to a change, I change not.[27]

In the repetition of the idea of a force directing movement—the sun shapes the course of the flower; the flower turns and bends as the sun bends—one finds that the movements of the sun and flower suggest a curve. Even the words "rise" and "fall," "die" and "live" suggest, in their contexts, a cycle, each stage a requirement for the next: one rises to fall and falls in order to rise and so on. The repetition of "thus" and the use of "change" suggests circularity. And in the poem change becomes a constant, and the dance of sun and flower becomes an instance of steadfastness.

Of course, one cannot attribute to Sidney the start of the English revolution either in poetic arts or in science. Why his poetry, written in the last quarter of the sixteenth century, should have such a fundamentally different shape is unclear. But the world constructed in the tropes of Sidney and his contemporaries must have started educated Englishmen of the next generation with fundamental assumptions very different from those suggested by Galenic medicine.

In June 1583, Philip Sidney accompanied the Polish Prince Albert Alasco to Oxford, where the Prince was entertained by a dispute between Giordano Bruno and the Doctors of Theology.[28] The substance of Bruno's message is contained in George Abbot's *The Reasons Which Doctor Hill Hath Brought, for Upholding of Papistry*, published in 1604: "[T]elling vs much of *cheutrum & chirculus & circumferenchia* . . he vndertooke among very many other matters to set on foote the opinion of Copernicus, that the earth did go round, and the heavens did stand still."[29]

The introduction of the "new science" to England, however, was not the work of Bruno. In fact, another good friend of Sidney's—the mathematician, astrologer, and mystic John Dee—had already accepted Copernican heliocentrism. By

the time Bruno arrived, Sidney had written his great poetry—poetry that already embedded the premises of Bruno's new idea. Bruno dedicated his treatise *Spaccio della bestia trionfante* in 1584 to Sidney, telling him that the reform of the heavens is also a reform of the microcosm, man. But Sidney had already written *Astrophil and Stella*, a poetic production that, according to another dedication to Sidney, *De gli eroici furori* (1585), Bruno seems to have read on his trip and admired.[30] Sidney certainly did not make any scientific discovery, but as Bruno seems to have recognized, Sidney's poetry, the poetic style that would come to define English literary art, had as its informing presence a new way of looking, of thinking, of writing.

The heirs to Sidney are many. But in particular those writers of the next generation, Ben Jonson, John Donne, and their circle, have their minds stamped by the language and way of thinking. It will be our task, however, to turn to another member of that generation and circle: William Harvey.

The Poetics of Harvey

Harvey was a theatrical performer, for from 1615 he was the Lumleian lecturer. Such public anatomies were performances. According to the charter of the United Company of Barber-Surgeons, given them in 1540, Henry VII authorized the taking of hanged felons for dissection. Since drawing and quartering was the usual accompaniment to hanging, the plan to dissect felons was only moving a popular outdoor spectacle indoors, where the public might be more select.[31]

Yet the public anatomy had other affinities with performance beyond the morbid spectacle of punishment. The spaces of anatomical presentations shared with playhouses the name theater. And both were theatrical spaces. An order issued in 1567 for the Barber-Surgeons' anatomies states that "there shall be pillars and rods of iron made to bear and draw curtains up, and about the frame where within the Anatomy doth lie, and it is wrought upon for because that no person or persons shall behold the dissections of the body . . . . until the Doctor shall come and take his place to read and declare upon the parts dissected."[32] There was an understanding of the dramatic nature of such occasions. By the time Fabricius lectured at Padua, the anatomical theater had come to resemble the Globe Theatre with its interior towering tiers for spectators and its crowded street-side stalls for shoppers. But even before the anatomy achieved its characteristic theatrical shape—the first is reputedly founded by Rondelet thirteen years after the publication of *De Humani Corporis Fabrica*[33]—Vesalius had transformed the anatomy lesson. Before Vesalius anatomy had included a lecturer, who read from Galen or Aristotle or some other authorized text, and a demonstrator, who pointed to the actual bodily details that illustrated the text. Vesalius became one of the first anatomists to handle the body directly, to point and speak at the same time, in fact, to read the words that he himself had written. The anatomist had become a writer, instructing a large audience on a subject for which the most complete authority was not a book but the lecturer

himself, who spoke and demonstrated what he spoke.

By the time of Harvey, English physicians had added anatomy to their course of study and secured rights of dissections similar to those of the Barber-Surgeons. In 1581 Lord Lumley and Richard Caldwell established a series of lectures at the Royal College of Physicians at Amen Corner, where a room was built to accommodate the lectures. The hour-long lessons were to be read twice a week, on Wednesdays and Fridays, for six years, during which time the complete body and its parts would be examined. In words that echo the preface to *Tottel's Miscellany*, Holinshed's *Chronicles* (1587) describes the lectures as open to any "diligent hearers . . . whether he be learned or unlearned."[34] Knowing who attended such demonstrations seems difficult. Treatises make it clear, however, that the lectures were aimed at relieving the ignorance of all practitioners, licensed or unlicensed. The Barber-Surgeon's anatomies are said to have "become one of the popular sights of London. . . . The annual event lasted for three days and was followed by a banquet. Its purpose was not to provide a spectacle for seekers of sensation but to raise the level of general knowledge."[35] Contemporary etchings that depict anatomies show them to be a combination of wonder-cabinet and moral exercise, to which not only men but women, children, and dogs might resort.

Because of the desire to diffuse the learning to a diverse audience, the Lumleian lectures were given in both Latin and English. The first year was devoted to the epitome, an overview of the whole of surgery, at the end of which the body of a human was to be dissected. The second year was devoted to swellings and a human trunk anatomized; the third to wounds and the head opened; the fourth to ulcers and limbs dissected with particular attention to muscles, sinews, arteries, veins; the fifth to the skeleton, along with the use of medical instruments; the sixth to the use of surgery and of medicine.

Harvey gave the Lumleian lectures from 1615 to 1656. His notes of his epitome and first dissection survive, their epigraph drawn from Virgil's Third Eclogue: "I begin with Jove, O Muses. All things are filled with Jove." The notes—nearly two hundred pages long—offer a fascinating glimpse into both the circumstances of the lectures and the mentality of the lecturer. They also reveal the poetics of a scientist. The notes are in Latin, with abbreviated references to authors Harvey wished to mention and with English phrases that seemed to have been cues for some illustration, aphorism, or witticism. At the beginning of the lectures he compares the dissection to a meal that he will "serve in their iij courses." The three courses vary in taste and location, and Harvey tries to hold the auditors' understandings by moving from the least to the most savory meal, from the furthermost room to the great hall: thus, he moves from the lower venter, "nasty yett recompensed by admirable variety" to "the parlor" (the thorax) and finally to the "divine Banquet of the brayne."

To aid his performance, he carefully scores his notes with accompanying

gestures as an actor might. In his notes to 5r, next to the five features of each bodily part—site, shape, quantity, motion, division—he sketches a hand, showing the gestures he plans. He will raise a different finger for the first three, apparently wiggling four fingers for "motion," and then spread all five fingers for "division."[36]

Throughout, what emerges is the script for a performance. Harvey spices the action with verbal attention-grabbers. He alludes to colorful locals, particularly other physicians whom the audience would recognize: "Long Harry" (Henry Saville) is used to illustrate a "gangrel" body. Ralph Wilkinson, Harvey's predecessor at St. Bartholemew's Hospital, illustrates gluttony. Harvey claims Wilkinson, known for his prodigious appetite, would eat a whole pig right off the spit. He mentions the evening fevers of Sir Robert Wroth, patron of Ben Jonson and son-in-law of the poet Philip Sidney's brother Robert. Some well-known London specimens are mentioned, including "the man behind covent garden [with a herniated testicle] bigger than his belly." Speaking of the way that plumstones and grape skins work themselves through the bowel undigested, Harvey even uses himself for illustration, describing how he retrieved his own gold ring from his faeces.[37]

In the notes, vivid images and snippets of narrations appear, undoubtedly to be fleshed out in the actual performance. He describes different body types and gaits: some people have a "measured regular, step" like "the executioner," while others "move about here and there in a disorderly confusion like ducks." Some images may be well worn: the head is the "domicile, shrine, citadel of the spirit"; the lower venter is a "kitchen shop"; the skin is "the rampart and bulwark." But quite often the comparisons surprise, as when he describes splenetic excitement as "motion from the lower Hous." Or when he states that fat prevents drunkenness, the way that "a layer of fat on a stew prevents the vapor from rising." The relationship between spleen and liver-stomach is that between the kitchen and the wash-house. He describes the journey from the colon to the rectum as from St. Paul's to Leadenhall Market—one street with many names. The diction is sometimes coarse but unforgettable, as when he uses the image of what he calls a "Hens-ars" to describe musculature.[38]

Harvey's images often reveal the kind of plenitude familiar from the poets after *Tottel*, as in his discussion of the movement of the bowels' muscles, where he likens it to "the pudding wife's hand. Example of motion is snails and leeches. Undulant motion as worms, wherefore mica placed on the shell is moved; as whip; wave in the water; a cloth now fixed in all parts now movable."[39] Sometimes the descriptions approach true poetry, as when he writes about the heart as a source of heat for the body:

> like the citadel and home of heat, lar of the edifice, fowntayn, conduit, hed. Conical shape, like a pine cone; in smelt a pyramid; in birds a rounded cone; in the mackerell a tetrahedral, triangular shape. . . .
>
> In quantity the heart of man is large, wherefore timid, wherefore courage from

> a common intelligence; in length 6 fingers, in width 4. It is large in the timid hare, stag and ass, because the heat is less dispersed. For vigor results from the heat of blood; therefore [we have] the irascible [person]; on contrary, [those] slow to fear, do not fear to become angry, for in them the bubbling of the blood [is] as a bubbling lake, but with great repose they swiftly cool down.[40]

Although written in a mixture of Latin and English, the succession of images, the oscillation between the quantified and the poetic, even the human expression of quantity, remind one of Hamlet describing humans as a work of art. Harvey also waxes poetic in describing the genitalia—"*by the string tyed to eternity*"—and discussing at length the beauties and uses of sexual union. The line on respiration, whether quoted or not, is striking: "soe curst children by eager crying grow black and suffocated."[41]

Undoubtedly Harvey did not employ the vividness of the descriptions, their plenitude, their reliance on common but surprising similitudes and experiences to poeticize his practice but to get his points across to a large and perhaps uneducated audience whose memories might be unsteady. Because spectators were often positioned quite far from the bodily site being dissected, Harvey would choose vivid comparisons to describe what his auditors could not see: the tunic of the stomach was "not like woven straw, but like silke-worms webb and spiders; snayle"; the configuration of the mesentery of the small bowel is "*a ruff; frensh mallow lef.*" The veins around the liver and spleen are "like the

Exterior to the University of Padua building that housed the anatomical theater, circa 1600

roots of a tree to the intestines. . . . Wherefore here the portal [vein] is the trunk of the tree." Apparently, in fact, Harvey uses the image of the tree to organize the whole part of the lecture. Throughout his dramatic explanation of the diastole and systole of the heart it appears that Harvey made use of a glove which he inflated—comparing Galen's idea of the pulse to his own.[42]

It is not surprising under the circumstances that Harvey's allusions are not always to medical texts. He knows Albrecht Dürer's studies of proportion in *Heirinnen sind begriffen vier Bücher von menschlicher Proportion*. He also refers to statues of athletes in which the penis has been drawn up into the body. The Bible and history are both favorite sources of anecdotes and aphorisms. He reminds his audience what a humped back looks like by mentioning Launcelot Gobbo from *Merchant of Venice* and the weight of the "Gutt" by allusion to Falstaff: "God keep lead out of me! I need no more weight than mine own bowels." He also alludes to *Romeo and Juliet*.[43]

Throughout, Harvey seems to be aware of the paradigmatic nature of his studies, and he seems to see them, like

other arts, modeled on and modeling organizational structures. For instance, in his lectures he states that "politicians [can acquire] many examples from our art." He often draws the points of his examples himself, extending from physiology into other areas of human inquiry and concern. His comparison of the heart and the brain, for instance, moves beyond the purely physiological:

> [T]he empire of the heart extends more widely in those in which [there is] no brain. Perhaps [the brain is] more worthy than the heart . . . because it is better to be [and to live] well than simply [to live sluggishly]. For that reason since all animals have one most perfect part, man [has] this, excelling all the rest; and through this the rest are dominated; it is dominated by the stars wherefore the head [is] the most divine, and to swear by the head; sacrosanct; to eat [the brain is] execrable.[44]

Harvey, then, sees himself as an artist and performer like other artists, using images to make ideas visible, to organize and communicate ideas, sharing with those artists, borrowing from them, giving back to them. Like the poets, too, for all his revolutionary zeal Harvey still needs the Galenic and Aristotelian past. So, for instance, this revolutionary explorer of the motion of the blood, of the action and function of the heart, and the whole nature of the mechanism of the body espouses the heart as heat source, the lungs as refrigerator. But while he speaks of "sooty vapors," he has problems with the blood as "boiling pottage."[45]

That is, Harvey, like Sidney, is an artist trying to free his art from the errors of the past. It is little wonder that as in the poetry of the generation before, Harvey questions the linearity of Galenic ideas. He initials a crucial passage in his notes that questions Galen's notion of the origin of the veins in the liver, thus upsetting the irrigation model of the blood. He will offer to replace innate motion of the arterial pulse by another force acting upon it, and he will postulate that the moderating balance of antitheses, central to the Galenic body, needs to be replaced by a more complex interaction of parts. And he will make his most important discovery—circulation.[46]

Is there a relationship between Harvey's immersion in discourse outside of medicine and the change from linear to circular motion? In his lectures it is clear that Harvey frequently relies on symbols that had become crucial to the cultural discourse, a discourse shaped in large part by the great shapers of Elizabethan language, the poets. Moreover, it is the power of the image of the circle to illustrate the heart's form, placement, and function that shapes Harvey's discovery.

The heart is, according to Harvey, "the principal part because [it is in] the principal place, as in the center of a circle, the middle of the necessary body." "[T]he beat of the heart produces a perpetual circular motion of the blood." Harvey's images of the circle and circulation may have derived from his familiarity with the "pelican," an alembic in which the neck bends to reenter the beaker at a lower point in order to circulate its contents. His description of the heart and veins alludes to an alembic,

the "containing and concocting vein" that stretches from the heart, where there exists "abundant heat" and "which is the most principal place in the center of the body." Later he mentions alembics and particularly the serpentine, a retort with a coiling, not a straight, neck.[47]

Yet even without the alembic, Harvey would have chosen the shape of the circle for its tremendous symbolic significance. In a passage on the head, Harvey marks these notes with his signature as being original and of special significance: "WH because nature makes all things round unless for some other reason; because [it is] the most perfect shape and for the sake of security. Moreover, nature [is constantly] perfective, wherefore the sky is round and most plants are round; bones are round. Many other reasons from anatomy for me X." The "X" at the end also marks his specific interest in these thoughts. Harvey seems predisposed to find centers and circles, disposed not because of any physical principle but because of a metaphysical one, a principle given shape through the metaphoric possibilities of his age.[48]

Harvey's discovery certainly seems harmonious with the dominant images of the poets of the time. One, Ben Jonson, a mutual friend of Thomas Hobbes, had written of the residence of Sir Robert Wroth's father-in-law a poem called "To Pennshurst," which was published the year of Harvey's first Lumleian lectures. That poem is structured by the image of circles, magnetism, and circulation. The owners dwell at a center to which all aliment flows and from which food and spirit are disbursed.[49] Is that an early image of the heart's function that Harvey was later to realize in his work?

The center from which and to which circulation occurs is a dominant trope of the day. Donne's work, noted for its interest in the "new science," offers the most familiar and striking examples. Donne knew anatomy, having spent time in the household of his stepfather John Symmings, a president of the Royal College of Physicians. Donne's poems testify to his acquaintance with anatomical detail. For instance, he is one of the first writers to use the word "skeleton," and he seems to understand the sutures of the skull.[50]

Donne's first published work, "Anatomy of the World," makes little contribution to anatomical literature but nevertheless offers an interesting discussion of the breakdown of the older paradigmatic structures. In the decline of humanity from the time of Adam and Eve, when the earth was round, not pockmarked and uneven, the structure of the circle, he writes, has been lost. Although Donne finds a Copernican cosmology unsettling, he derides the Ptolemaic view for its linearity: "nor can the Sunne / Perfit a Circle . . . So, of the Starres which boast that they do runne / In Circle still, none ends where he begunne." What is true of the macrocosm is true of the microcosm. The trouble is, as Donne writes, that a world "rotten at the hart" has also corrupted those relationships that the heart typified: "Prince, Subject, Father, Sonne" are "all in pieces, all cohaerence gone." The solution is to find the circles, to restore the heart, to recover the virtue that, acting

like Gilbert's magnet, will reconfigure everything through its attractive powers.[51]

The poem underscores the need to shift views, to shift paradigms, to see differently. One can readily appreciate why, operating in such an atmosphere, the structure of the circle and its importance might impart excitement to Harvey. He has found Donne's missing circle in the heart of man. It is Donne's language, not his anatomy or physics, that makes an important cultural contribution to science by helping reinforce a disposition begun in the rhetoric of Sidney and carried out in the philosophy of neoplatonism, the discoveries of Copernicus, and the trade to the West Indies.

If we can believe that language creates a disposition for observation, then the well-known lines from Donne's "Valediction Forbidding Mourning" are even more relevant to Harvey. Also produced in 1611, the poem uses one of the most famous circle images of the period, the compass:

> And though it [the fixt foot] in the center
> sit,
> Yet when the other far doth rome,
> It leanes, and hearkens after it,
> And growes erect, as that comes home.
> Such wilt thou be to mee, who must
> Like th'other foot, obliquely runne.
> Thy firmnes makes my circle just,
> And makes me end, where I begunne.[52]

Coming to such lines after reading Harvey's 1616 notes, one cannot help but be struck by the similar diction interfusing science and poetry, the similar use of illustration. But even more striking in the image of the compass is the idea of a center that rules a circle but that also occupies a position on the circle's periphery. That, in fact, is the uniquely different and crucial image for both Donne and Harvey. In *De Motu Cordis*, written in 1628, Harvey describes the blood as "flow[s] by the veins from the circumference on every side to the centre . . . the blood in the animal body is impelled in a circle, and is in a state of ceaseless motion."[53] The blood flows in a circle yet flows through a center, like the traveling foot of Donne's compass. One may also note the resemblance of this passage to others from the *Prelectiones*. As in the lecture notes, here the circle offers a compelling symbol that Harvey seizes on to understand his observations and to formulate his ideas.

But just how dependent was Harvey on literary discourse? Historians of science and literature alike have tended to find Harvey's writing lacking poetic graces. Marjorie Hope Nicolson acknowledges Harvey's nonscientific obsession with the idea of the circle, yet she uses the words "report," "exact," and "literal" to describe his work.[54]

Marie Boas called *De Motu Cordis* a "singularly tough and tight piece of scientific reasoning," "a short and remarkably trenchant book." Despite this characterization, Boas noted the poetic and even mystical leanings that come through in the work and that may have propelled Harvey to his study: "*De Motu Cordis* is, in fact, filled with as many dithyrambs in praise of the heart and the circular motion. . . . It is all very mystic." Similar observations about

Harvey's lyricism have been made by others.[55] In fact, a poetic consciousness clearly drives Harvey's discovery.

After concluding his demonstration of the circular motion of the blood in *De Motu,* Harvey goes on to make arguments for the "convenience and necessity" of his explanations that rest on what he himself calls the "familiar reasonings" of his age:

> In the first place, since death is a corruption which takes place through deficiency of heat, and since all living things are warm, all dying things cold, there must be a particular seat and fountain, a kind of home and hearth, where the cherisher of nature, the original of the native fire, is stored and preserved; from which heat and life are dispensed to all parts as from a fountain head; from which sustenance may be derived; and upon which concoction and nutrition, and all vegetative energy may depend. Now, that the heart is this place, that the heart is the principle of life, and that all passes in the manner just mentioned, I trust no one will deny.[56]

His explanation seems a concatenation of poetic justifications, justifications that are moreover nearly identical to passages cited from the *Prelectiones*. Rather than being "dry," the writing in *De Motu* shares many of the dramatic features of the lectures. Perhaps for that reason Harvey called the treatise a "demonstration," not from the Euclidean term but from the practice of the public anatomical performance.

Among the features *De Motu* shares with the *Prelectiones* are the illustrations. The glove remains a favorite: "the arteries dilate, because they are filled like bladders or leathern bottles; they are not filled because they expand like bellows" (68, 81). A fetus may be compared to "a soft worm" (136). In discussing the rapidity with which blood may pass through the body, he at first compares the motion to springs and rivulets permeating the earth but then chooses a more common metaphor: "It is well known that persons who use the Spa waters or those of La Madonna, in the territories of Padua, or others of an acidulous or vitriolated nature, or simply swallow drinks by the gallon, pass all off again within an hour or two by the bladder" (101). While the comparison is cleaned up considerably for a scholarly publication, the particularity of place and the list come across with a sly wit—moving from the fastidious health seeker to the drunkard. Also present are the plenitudinous lists of animal comparisons (85).

Sometimes the language verges on metaphysical nicety. "Oysters, mussels, sponges, and the whole genus of zophytes or plant-animals have no heart, for the whole body is used as a heart, or the whole animal is a heart" (128). At times, the thoughts can be both beautiful and sublime: "I have also observed the first rudiments of the chick . . . in the guise of a little cloud. . . . In the midst of the cloudlet in question there was a bloody point so small that it disappeared during the contraction and escaped the sight, but in the relaxation it reappeared again, red and like the point of a pin; so that betwixt the visible and the invisible, betwixt being and not being, as it were, it gave by its pulses a kind of representation of the commencement of life" (86). In the question of being and non-being

the point of pulsating blood becomes the center of the circle, a representation of an entire theory, the fragile mark from which incredible implications unfold. But they unfold through the words and mind of a man imbued in the poetry of his craft, the art of his science, the discourse of his age, as he proclaims dramatically in one part of his argumentation, sounding like a dramatic character rather than a man of science:

> Nay, has not the blood itself or spirit an obscure palpitation inherent in it, which it has even appeared to me to retain after death? and it seems very questionable whether or not we are to say that life begins with the palpitation or beating of the heart. The seminal fluid of all animals—the prolific spirit, as Aristotle observed, leaves their body with a bound and like a living thing; and nature in death, as Aristotle further remarks, retracing her steps, reverts to where she had set out, and returns to the end of her course to the goal whence she had started. As animal generation proceeds from that which is not animal, entity from non-entity, so, by a retrograde course, entity, by corruption, is resolved into nonentity, whence that in animals, which was last created, fails first and that which was first, fails last. (85)

The diction, sometimes that of a scientist, sometimes that of a poet, is structured by an underlying awe. The image is a circle in which the originating point, from which all unfolds and to which all retraces, might be the blood itself, or even a spirit beyond the blood.

It would be useless and repetitive to point out all the poetic features of *De Motu*, all the uses of the circle, beginning with a dedication to the sunlike majesty of Charles I, in which Harvey constructs the metaphors that will recur throughout the work: "The heart of animals is . . . the sovereign of everything within them, the sun of their microcosm, that upon which all growth depends, from which all power proceeds" (61); and ending with the reiteration of the importance of his paradigm for a prince understanding his duties as "the heart is the source and foundation from which all power is derived, on which all power depends" (137). The work makes clear its own poetic importance. Just as symbolism infuses it, its symbolism (so Harvey claims) should infuse any study—political, anatomical, astronomical, poetic.[57]

Most important for understanding Harvey's debt to poetic discourse, however, is his description of the discovery itself: "I began to think," after observations tended to contradict Galen, "I began to think," he writes, "whether there might not be a MOTION, AS IT WERE, IN A CIRCLE." He continues: "Now, this I afterwards found to be true; and finally saw" (101). Here Harvey announces that in trying to account for an unexplained phenomenon, he had looked for a model. He didn't SEE the circulation of the blood until he had postulated it. That is, the structure preceded the discovery. The structure had to be available for him. Having abandoned straight lines like the poets from Sidney on, Harvey sets out to find a circle. He had wondered, like Jonson wondering about the movement of dust in an hourglass, could this figure of perfection, this figure of the poets, describe the blood. Like Jonson, he had answered yes.[58]

The joy of discovery comes for Harvey not from the triumph of truth. In fact, he never sees the motion he reports; capillaries that completed the circle had not yet been observed. In *De Motu*, as in his lectures, Harvey substitutes an image for what the spectator cannot see. Harvey's joy comes not from the truth of his discovery but from its fitness, the aptness of metaphor, the beauty of explanation, from art. As Harvey makes clear, the "circle" is only a way of speaking about the blood, only a very powerful way of speaking: "This motion we may be allowed to call circular." But precedents exist for such poetic license in the circular movement of rain, evaporation and condensation. "By this arrangement are generations of living things produced; and in like manner are tempests and meteors engendered by the circular motion, and by the approach and recession of the sun." From this point begins the paean to heart, sun, household.[59]

Harvey seems aware that he has given the structure, the metaphor, the meaning, without the visual "evidence." He seems aware that, like the poet, he might be accused of simply using words, of painting pictures of what could be. He thus proposes to give certain further proofs, "lest anyone should say that we give them words only, and make mere specious assertions without any foundation [he could have said 'fictions'], and desire to innovate without sufficient cause."[60] He understands the use of the paradigm and the brutal newness of that to science. A poet writing about a place like Pennshurst might safely combine images and ideas of center, hearth, power, light, and nourishment. But for a physician to write this way about the heart could provoke scorn. Yet Harvey makes clear that a metaphor drove him to see if he could find in fact what in poetry would be in the heart.

What I have tried to demonstrate is not far from the more or less recent observations of writers of science. As Stephen Jay Gould, has put it: "Facts are not pure and unsullied bits of information; culture also influences what we see and how we see it. Theories, moreover, are not inexorable inductions from facts. The most creative theories are often imaginative visions imposed upon facts; the source of imagination is also strongly cultural."[63]

In 1944 Gunnar Myrdal had already written about how culture shapes assumptions about the universe, questions to ask, and facts as well as interpretations and reactions. Scientific discoveries require not only a "new mentality" but also a new set of metaphors.[62] As Marjorie Hope Nicolson, who traced the influence of science on poetry, nevertheless observed: "Perhaps I am really saying that many great scientists of the past were poets, and some of them mystics. They made their greatest discoveries by processes easily comprehensible to poets. They continued to speak a language that had been common to poet and scientist."[63] Harvey himself pays tribute to getting the image right when he rejects the image of the anchor to stand for the relationship between the veins and the viscera. The viscera does not anchor the veins, he writes. Instead it is "as cotton to keep a Jewel."[64]

Of course, the poets never were far disconnected from science, as even

Tottel's Miscellany shows. But the poets seem to have aided the establishment of a new paradigm, not through their knowledge but through their language and mentalities. On the other hand, the poets understand that the new science implies a paradigmatic shift that will reshape all human enterprises: "Moving of th'earth brings harmes and feares, / Men reckon what it did and meant, / But trepidation of the spheares, / Though greater farre, is innocent."[65] When Donne compares the simple, elegant explanation of Copernicus to the more clumsy one of Ptolemy, he reflects that the paradigm shift, well underway, not only terrifies but suggests changes in all conceptual and meaning-making activities. As a poet recognized this, he, like so many others, seized upon its significance and broadcast it for others to seize and broadcast. In this way we find that poets were at both the center and circumference of movement.

Notes

1. Philip Sidney, *Astrophil and Stella*, in *The Poems of Sir Philip Sidney*, ed. William A. Ringler, Jr. (Oxford: Clarendon Press, 1962), 165.

2. Ibid., 232.

3. See, e.g., Benjamin Lee Whorf, *Language, Thought, and Reality* (1956; reprint, Cambridge, Mass.: M.I.T. Press, 1971); S. I. Hayakawa, *Language in Action* (New York: Harcourt, Brace, 1940). On the influence of language on medical discovery, see Michel Foucault, "What Is an Author?" *Language, Counter-Memory, Practice: Selected Essays and Interviews*, ed. Donald F. Bouchard, trans. Donald F. Bouchard and Sherry Simon (Ithaca: Cornell University Press, 1977), 113 ff. Devon L. Hodges, *Renaissance Fictions of Anatomy* (Amherst: University of Massachusetts Press, 1985), cites Vesalius as the model for all the literary anatomies he discusses.

4. Dannielle Jacquart and Claude Thomasset argue that "by means of language, power [in medieval medicine] was exercised over the way things were represented." See Jacquart and Thomasset, *Sexuality and Medicine in the Middle Ages*, trans. Matthew Adamson (Cambridge, Eng.: Polity Press, 1988), 8.

5. Charles B. Schmitt, "Aristotle Among the Physicians," *The Medical Renaissance of the Sixteenth Century*, ed. A. Wear, R. K. French, and I. M. Lonie (Cambridge, Eng.: Cambridge University Press, 1985), 14.

6. From the epigraph to Thomas Vicary, A Profitable Treatise of the Anatomie of Mans Body (New York: Da Capo Press, 1973).

7. Ibid., A 4r.

8. Frances Bacon, "Epistle Dedicatory," in *The Great Instauration*, in *The Complete Essays of Francis Bacon, Including the New Atlantis and Novum Organum* (New York: Washington Square, 1963), 154.

9. William Harvey, *Lectures on the Whole Anatomy*, trans. C. D. O'Malley, F. N. L. Poynter, and K. F. Russell (Berkeley: University of California Press, 1961), 235; all citations of Harvey's lectures are to this volume.

10. Schmitt, "Aristotle," 14.

11. Richard Tottel, "The Printer to the Reader," in Tottel, *Tottel's Miscellany* (1557–1587), ed. Hyder Edward Rollins, rev. ed. (Cambridge, Mass.: Harvard University Press, 1965), 2.

12. Ibid., 3; lines 14–15 echo Petrarch's *Sonetto in Vita*, no. 150, ll. 1–2. Other suggested sources include *Sonetto in Vita*, nos.

123, 137, 155, 169, *Trionfo d' Amore,* and *Sestina in Vita,* no. 1.

13. Robert G. Frank, Jr., *Harvey and the Oxford Physiologists: Scientific Ideas and Social Interaction* (Berkeley: University of California Press, 1980), 2–9.

14. *Tottel's Miscellany,* 8. *Sonetto in Vita,* no. 91 is the model for that sonnet, as is Wyatt's "The lover for shamefastness hideth his desire within his faithful heart," ibid., 2.

15. Sidney, *Astrophil and Stella,* 191.

16. "The complaint of a hot wooer delayed with doubtful cold answers," "The answer," "An other of the same," "The answer," "Of change in mind," and "The promise of a constant lover," in *Tottel's Miscellany,* 235–39.

17. Sidney, *Certain Sonnets,* in *Poems of Sir Philip Sidney,* 146.

18. Sidney does not reject totally the lessons of Petrarch (e.g., sonnet 15, p. 144), yet he most frequently follows classical and contemporary forms, ideas, and rhythms. Sonnets 12–14 use classical models; sonnets 3, 4, 6, 7, 24, 26, and 27 use popular Italian, Spanish, and English settings; ibid., 142–43, 136, 137, 139–40, 153, 155–57.

19. Sidney, *Astrophil and Stella,* 201–4, 206–8, 210–12, 217–21, 166. Sonnets 71 and 72 describe the excitement of desire; song 2 tells of the stolen kiss; sonnets 73–74 tell of Stella's reaction; and sonnets 79–82 eulogize the kiss and kissing in general; songs 4 and 8 concern the pleaded-for-but-not-accomplished sexual union.

20. Sidney, *Certain Sonnets,* 140–42.

21. Ibid., 225, 213, 187, 214, 179, 207, 213.

22. Ibid., 172–73, 179, 205, 236–37 (hot heart: sonnets 16, 28, 76, 108; lover cools: sonnet 8; heat causes song: sonnet 81; heart for introspections: sonnets 4, 5, 32, 38, 39, 40, 43, 88, 105; mind connected with love: song 5.

23. Sidney, *Astrophil and Stella,* 223–24. Sonnet 89 makes complex use of the exclusive, binary rhymes "night" and "day."

24. Ibid., 185–86, 208, 214–15, 217, 201.

25. Ibid., 169, 218.

26. Sidney, *Certain Sonnets,* 140.

27. Ibid., 154.

28. Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (1964; reprint, New York: Random House, 1969), 206–7.

29. Ibid., 208.

30. Ibid., 188, 220; Ringler, "Commentary," *Poems of Sir Philip Sidney,* 435, n. 1.

31. Donne's "Love's Exchange" makes it clear that "Rack't carcasses make ill Anatomies." John T. Shawcross, ed., *The Complete Poetry of John Donne* (Garden City, N.Y.: Doubleday, 1967), 123.

32. Quotation from Jessie Dobson and R. Walker, *Barbers and Barber-Surgeons of London: A History of the Barbers' and Barber-Surgeons' Companies* (Oxford: Blackwell Scientific Publications, 1979), 40–41.

33. E. Bauer, *La Science Moderne, de 1450 a 1800* (Paris: Presses Universitaires de France, 1969), 151.

34. Quotation from Harvey, *Lectures,* 3.

35. F. N. L. Poynter, ed., *Selected Writings of William Clowes, 1544–1604* (London: Harvey & Blythe, 1948), 15.

36. Harvey, *Lectures,* 21, 28, 29.

37. Ibid., 32, 85, 123, 137, 76.

38. Ibid., 33, 35, 38, 60, 81, 97–98, 64, 129, 77.

39. Ibid., 78.

40. Ibid., 175.

41. Ibid., 124 ff., 201.

42. Ibid., 79, 64–65, 187, 189. The glove appears to have been a favorite prop throughout Harvey's lectures.

43. Ibid., 32, 148, 63, 33, 68; Falstaff's line is from *1 Henry IV,* act 5, scene 3, l. 36.

44. Harvey, *Lectures,* 215, 214.

45. Ibid., 170, 159, 190.

46. Ibid., 178, 188.

47. Ibid., 171, 191, 178, 203–4.

48. Ibid., 208. It could be argued that Harvey imbibed the continental neoplatonism that informed much of science; see Thomas Kuhn, *The Copernican Revolution* (Cambridge, Mass.: Harvard University Press,

1957), 128–33. Yet those ideas, even without definite neoplatonic meanings, had come to reshape discourse and consciousness in England. Sidney's interest in Bruno, for instance, does not precede his interest in circularity but accompanies it.

49. Ben Jonson, "To Pennshurst," *The Complete Poetry of Ben Jonson*, ed. William B. Hunter, Jr. (New York: W. W. Norton, 1968),77–81.

50. Kuhn, *Copernican Revolution*, 193–95; Charles Monroe Coffin, *John Donne and the New Philosophy* (New York: Humanities Press, 1958); Anthony Low, "Love and Science: Cultural Change in Donne's *Songs and Sonnets*," *Studies in the Literary Imagination* 22, no. 1 (1989): 5–16; Milton Allan Rugoff, *Donne's Imagery: A Study in Creative Sources* (New York: Russell & Russell, 1962), 55 ff. Donne's biographers neglect Symmings and the medical connection, partially because little information is available and partially because of the precedent of Izaak Walton's *The Life of Dr. Donne* (1640). See, e.g., Edward Le Comte, *Grace to a Witty Sinner: A Life of Donne* (New York: Walker and Company, 1965).

51. *Complete Poetry of John Donne*, 280, 279, 278.

52. Ibid., 88.

53. Harvey, *On the Motion of the Heart and Blood in Animals* (1628), trans. Robert Willis, vol. 38 of *Harvard Classics*, ed. Charles Eliot (New York: P. F. Collier, 1910), 122.

54. Marjorie Hope Nicolson, *The Breaking of the Circle: Studies in the Effect of the "New Science" upon Seventeenth-Century Poetry*, rev. ed. (New York: Columbia University Press, 1962), 132–33.

55. Marie Boas, *The Scientific Renaissance, 1450–1630* (New York: Harper, 1962), 281, 285; Herbert Butterfield, *The Origins of Modern Science, 1300–1800* (New York: Free Press, 1957), 53; Charles Singer, *A Short History of Anatomy and Physiology from the Greeks to Harvey* (New York: Dover, 1957), 176. See also Singer, *A History of Biology to About the Year 1900*, 3d ed. (London: Abelard-Schuman, 1959), 102, for connection of anatomist and artist.

56. Harvey, *On the Motion of the Heart*, 122–23.

57. Traditionally poetic effusions occurred when any anatomist considered a major organ. Effusions on the heart often took a form similar to Harvey's, thus fashioning a rhetoric of medicine that subsequent practitioners would follow. See Vicary, *Profitable Treatise*, H 4–I 1; c.f. K 3r.

58. Jonson, "The Houre-glasse," *Complete Poetry*, 135–36

59. Harvey, *On the Motion of the Heart*, 101–2.

60. Ibid., 103.

61. Stephen Jay Gould, *The Mismeasure of Man* (New York: W. W. Norton, 1981), 22; Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton, 1989), 28.

62. Gould, *Mismeasure*, 23; Butterfield, *Origins*, 8, 13, 17, 26.

63. Nicolson, *Breaking*, 126.

64. Harvey, *Lectures*, 102–3.

65. *Complete Poetry of John Donne*, 87.

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Redefining Death in America, 1968

In August 1968, a committee of ten doctors, one lawyer, one historian, and one theologian redefined death for the medical profession and for the American public. Cessation of respiration and heartbeat were no longer considered adequate to determine death in all cases. This paper examines the motivations put forth by the committee for redefining death and places them in historical context. It reveals the subtle but powerful cultural effects of reifying technology and exposes some of the value-laden decision-making involved in medical research.[1]

The Ad Hoc Committee of the Harvard Medical School to Examine the Definition of Brain Death (the formal name of the committee) recommended four new standards: (1) unreceptivity and unresponsitivity, (2) no movements or breathing, (3) no reflexes, and (4) a flat electroencephalogram.[2] Explaining why it was necessary to undertake the unprecedented act of codifying a new definition of death, the committee underscored advances in technology as the principal motivation. Members stated that improvements in resuscitative and supportive measures had led to situations in which individuals with beating hearts could be maintained "alive" even though they were irreversibly brain-damaged—a situation that emotionally and financially drained not only patients' families but hospitals as well.

The primacy given that explanation obscured the impetus that had generated the urgency for reform, an impetus mentioned as a second factor—namely, the concern that traditional criteria for the definition of death had led to controversy in obtaining organs for transplantation. The proposed new criteria sought to limit controversy surrounding organ procurement by making it legal to remove a beating heart—the heart of someone who by contemporary popular and legal understanding was still living.[3]

The committee offered two reasons for redefining death—reasons based on mutually contradictory values. First, members said that a new definition would help reduce the emotionally and financially draining effects of resuscitative measures.[4] That motivation was predicated on a desire to relieve human suffering. The second reason was to reduce controversy surrounding organ transplantation. That impetus, however, sought to further scientific research even at the cost of prolonging human

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suffering. The track record of heart transplantation at the time makes that clear.

Heart Transplantation Controversies

The moral uncertainties surrounding heart transplantation in the 1960s were many. No animal heart transplants had been successful.[5] The early months of the "therapy" had a complete and completely predictable failure rate.[6] Human heart transplantation was, in fact, experimentation on human subjects conducted in complete view of an awestruck public believing that they were seeing the latest medical miracle. The media sensationalized the drama and excitement of each procedure, inspiring public awe and approval.[7] Notices of the deaths of transplanted patients days or weeks later, often published in less-featured reports, did not dampen popular amazement. The ethics of continuing to offer the procedure were, at best, questionable. In March 1968, scarcely two months after the world's first human-to-human heart transplant in South Africa, three of the top United States cardiac specialists called for a moratorium. Dr. George Burch of Tulane University was particularly direct in his denunciation. He would refuse to select any patient for a cardiac transplant because, as he said: "[O]nce you take his own heart out, you know he's going to die . . . his new heart will be rejected by his body because we are still unable to suppress the immune reaction."[8]

The Harvard committee's prioritizing of contradictory rationales eventually helped to shift the focus away from the controversy surrounding heart transplantation and towards technology as the reason for concern—specifically, "improvements in resuscitative and support measures." Significantly, however, the medical profession had been dealing with the disturbing effects of artificial life-support systems for well over a decade.

Artificial Respiration

The committee statement gave the impression that advances in respiratory technology were the principal development responsible for generating ethical concern.[9] "From ancient times down to the recent past," the committee instructed, "when the respiration and heart stopped, the brain would die in a few minutes. . . . This is no longer valid when modern resuscitative and supportive measures are used. These improved activities can now restore life.[10] Chief among the "improved activities" was the mechanical ventilator.

The iron lung was the technological predecessor to the ventilator.[11] Developed in 1929, the apparatus was itself an adaptation of earlier devices developed since the late nineteenth century. The patient reclined inside a round steel tank. The head remained outside the chamber, while the neck was supported by tight-fitting rubber collars designed to avoid pressure to the windpipe and voice box. Inside the tank, adjustable pumps applied intermittent positive and negative pressure. The iron lung saved the lives of hundreds of victims of poliomyelitis whose breathing had been impaired by the paralysis of intercostal muscles and diaphragm. The device was crucial in helping patients through

weeks or months of temporary paralysis. But, due to complications and the need for full-time nursing, it was an imperfect solution for long-term use.

One of the main innovations leading to the ventilator came in 1952 when Denmark physicians were faced with a catastrophic polio epidemic. After twenty-seven of the first thirty-one patients on respirators died at Blegdam Hospital, Drs. H. C. A. Lassen and Bjorn Ibsen attempted an innovation—a tracheotomy followed by mechanical ventilation from a manually-compressed anesthesia bag that had been adapted for that purpose. In all, 250 medical students worked in daily relays to manually ventilate approximately two hundred patients. Three years later, about twenty-five patients were still being kept alive through ventilation—a technological process that had since become automated.

With modifications, the use of mechanical ventilation grew, and by the late 1950s the respirator was used to treat illnesses and injuries beyond polio. Statistics from Massachusetts General Hospital are instructive. In 1958, sixty-six patients were kept on ventilators for twenty-four hours or longer. By 1982 the number had grown to approximately two thousand. The risks of numerous surgical procedures and illnesses were vastly reduced by use of the ventilator. Artificial respiration, clearly, had become one of the major achievements of modern medicine. Yet successes in medicine are rarely, if ever, unqualified. Ventilators—along with renal dialysis, intravenous feeding, and a panoply of other technologies and procedures—have not always assisted in restoring health. Often, they either prolonged dying or prolonged life indefinitely in a "vegetative" state.

A "new way of dying"

Members of the public and members of the medical profession expressed anxieties over the apparent prolongation of suffering. In January 1957, one woman anonymously shared her distress with readers of the *Atlantic Monthly*. She wrote poignantly of her husband's death at the hands of institutionalized medical care—a "new way of dying . . . the slow passage via modern medicine." After witnessing the torment of repeated surgeries, medications, oxygenation, and intubations, amid delirium and unconsciousness, she could no longer bear her husband's "torture":

> "They can't do this to you any longer. I must put a stop to it," I cried. . . .
>
> When the first doctor came on duty I accosted him and begged that they cease this torture. He explained that except under the most unusual circumstances they had to maintain life while they could. Very well, I thought, if it has to be so, so be it.[12]

But when a nurse arrived with a tray of medication, the author wanted to "kick her tray . . . and knock her from the room."

> She was here to snare him back just as he might have reached the other shore. I asked her why. "Doctor's orders," she

replied. "I am to give him a hypo." I staggered out the door; there was nothing else to do.

The *Atlantic* introduction also indicted "big metropolitan hospitals" for creating "an ordeal" that had "somehow deprived death of its dignity."

That anonymous account, although targeted at the general public, resonated with some physicians who had grown critical of what medicine had wrought. Dr. John Farrell, chairman of surgery at the University of Miami, read the widow's anguished memoir. In 1958, at a banquet address to a chapter of the American College of Surgeons, Farrell decided to forgo a "light and amusing" theme befitting the occasion. Instead, he echoed the widow's distress and spoke of the patient's "right to die." He concluded: "In our pursuit of the scientific aspects of science, the art of medicine has sometimes unwittingly and unjustifiably suffered. . . . [T]he death bed scenes I witness are not particularly dignified. The family is shoved out into the corridor by the physical presence of intravenous stands, suction machines, oxygen tanks and tubes emanating from every natural and several surgically induced orifices. The last words . . . are lost behind an oxygen mask."[13]

Farrell was not alone in revealing his moral qualms. His sensibility was echoed periodically in medical journals. The technologies invoked as examples varied, but the message was the same: An ever-widening list of technologies and procedures were being brought into use inappropriately for the supposed benefit of dying patients.

One of the more dramatic indications of medicine's growing discomfort with the problem—and an illustration of its increasing search for external moral guidance beyond its own institutions—occurred in 1957. In that year, the International Congress of Anesthesiology, concerned by ethical problems in the use of resuscitative measures, sought guidance from Pope Pius XII.[14] Troubled anesthesiologists asked for moral instruction to advise physicians as to when they had the right or obligation to begin resuscitative measures on unconscious individuals and, most important, when they were obligated to cease artificial resuscitative measures.

The Pope's response was read at the November congress. He stated that a physician must not act without authorization from the patient's family and that the family was bound to use ordinary, not "extraordinary," measures to prolong life. According to the "principle of double effect" of the Catholic Church, one act—specifically, terminating resuscitation—had two effects. The first and desired effect was to end human suffering. The second effect, namely death, was only the indirect result of a moral act. In such cases, terminating treatment was not only permissible but advisable.[15]

In March 1966, physicians held the First National Congress on Medical Ethics and Professionalism in Chicago. Dr. William P. Williamson of the University of Kansas Medical Center admonished physicians that, whether they liked it or not, the doctor's "skills, decisions, and the treatments he renders, often determines life or death for his patient."

Williamson provided a partial list of contemporary measures contributing to the dilemma. "Improved understanding of body physiology and chemistry, potent drugs, remarkably efficient mechanical respirators, pacemakers, and artificial organs, combined with aggressive medical and nursing care, have saved many lives, cured diseases, and solved many medical problems," he observed. "Yet, paradoxically, this very progress has created other problems."[16]

For Williamson, the problems were not medical but theological, social, and legal, and the profession needed nonmedical advice to deal with them. "[C]onsideration of the moral and spiritual aspects, as well as guidance of the family's thoughts and emotions, are proper functions of the clergy, either rabbi, priest, or minister," he continued. "Thus the team approach of physicians and clergy working together, with patient and family, is the ideal solution to this problem. At times, other professions may contribute . . . such as lawyer, social worker, or nurse."[17]

Prolonged suffering was becoming a concern at even regional medical meetings. It was the topic, for example, at the Wyandotte County Medical Society, which convened in Kansas City in 1966. Each of the attendees brought a clergyman as guest. The program's panel included a surgeon, a psychiatrist, an internist, a rabbi, a minister, and a priest. The meeting was far from the only one called to address similar moral anxieties. The Department of Medicine and Religion of the American Medical Association (AMA) helped form committees on medicine and religion in each state medical society. In turn, those committees arranged seminars and discussion groups to address the dilemma.[18]

Those efforts were part of a trajectory of concern growing in intensity since the 1950s.[19] The dilemma was not the result of a specific technology or procedure. It was rooted in a cast of mind that measured success by the ability to stall death—even in the face of death's inevitability.

If difficulty in knowing when to terminate treatment was a problem internationally as early as 1957, what rekindled fresh concern in 1968? Why was the focus so narrowly fixed on resuscitative measures, and why was redefining death chosen as the solution?

As was widely understood within the heart transplantation specialty and as the popular presses occasionally reported, the need to redefine death stemmed from the desire to reduce controversy in obtaining organs. Transplant surgeon Thomas E. Starzl recalled in his memoirs the first time that he heard of the idea of brain death. At the 1966 Ciba Foundation symposium on the ethics of transplantation in London, Guy Alexandre of Louvain, Belgium, told of extracting kidneys from "heart-beating cadavers." Starzl was "appalled" upon first hearing about the removal of organs from brain-damaged people with beating hearts. He "envisioned that the care of a trauma victim could be jeopardized by virtue of his or her candidacy to become an organ donor." Ultimately, however, he came to believe that his initial fears were unfounded. He was persuaded that once it became licit to remove organs from

brain-dead individuals, it became *more* likely that accident victims (i.e., potential donors) would be placed on respirators, thus *increasing* their chances of revival. Placing patients on respirators helped to preserve their organs, and, as Starzl phrased it: "With the wide acceptance of brain death in the Western world, all injured patients who come to the hospital in a helpless condition could have a fair trial at resuscitation."[20] Given the parallel though contradictory concern over the prolongation of dying, the source of Starzl's sense of comfort bears a striking irony.

Dr. Starzl described some of the difficulties involved for surgeons wishing to transplant organs before 1968—difficulties that led them to consider redefining death:

> Rather than trying to maintain a strong heartbeat and good circulation in the cadaver donors, the legal requirement before the end of 1968 was just the opposite. Because all such donors were incapable of breathing if the brain actually had been destroyed, they were supported by ventilators. The steps to donation began with the disconnection of the ventilator, which the public called "pulling the plug." During the five to ten minutes before the heart stopped and death was pronounced, the organs to be transplanted were variably damaged by oxygen starvation and the gradually failing and ultimately absent circulation.
>
> The strategies that could be used to minimize the organ injury under these circumstances were limited.[21]

If heart-beating cadavers facilitated organ transplantation generally, they were the *sine qua non* of heart transplantation specifically. That was widely understood within transplantation research circles. One physician even referred to the brain-death criteria as the "new definition of heart donor eligibility."[22]

Anxieties over prolonging dying clashed directly with the desires of medical researchers wishing to move ahead with experimentation in the controversial field of organ transplantation.[23] The Harvard committee statement turned the growing worry over prolonged suffering to its advantage, however, when it cast the need for a new definition of death as something that could facilitate treatment termination. But if prolonging life (or suffering) in order to further transplantation research chaffed against the contrary impulse to let people die, transplant researchers were confronted with a potential legal barrier capable of halting their research altogether: the possibility of criminal liability.

Human experiments in kidney transplantation in the 1960s had generated harsh criticism from within the profession. Heart transplantation compounded the controversy with a unique difficulty: While a healthy individual could donate one kidney and still function normally with the remaining kidney, a healthy human being could not donate a heart. Cadaver heart donations were tried and found unsatisfactory. The best sources for donations were severely brain-damaged individuals attached to respirators. The problem for transplant surgeons, however, was that such individuals were, technically, still alive.

Dr. John H. Kennedy put it bluntly. The donors of early human heart transplants, he said, "would not have been pronounced dead [at the time they had been pronounced dead] other than for their role as cardiac donors." In a 1968 letter to *JAMA*, Kennedy urged members of the AMA to "assume a leadership role" in considering new criteria of death. "If the criteria of clinical death are indeed to become more liberal to meet the demands of a new method of treatment of incurable human disease," he wrote, "the medical profession must assume a leadership role in the careful consideration of these criteria."[24]

In the same issue, *JAMA* editors concurred that transplantation presented problems concerning when and how to determine death. Unless the criteria for being "finally and irretrievably dead" are changed, "murder has been done." The editorial continued:

> Among the many problems surrounding the transplantation of vital organs . . . one of the most critical is this: When is the donor finally and irretrievably dead? When does one dare to relieve him . . . of his heart or his liver? . . . [I]f such organs are taken long after death, their chance of survival in another person is minimized. . . . [I]f they are removed before death can be said to have occurred by the strictest criteria that one can employ, murder has been done.

Two months later, the editor queried: "Can the transplanter afford to wait for a dying organ just to be certain that he is not also a surgical criminal"?[25]

The Harvard committee promulgated its criteria to avoid the kind of controversy that surrounded Dr. Denton Cooley, a transplant surgeon at St. Luke's Episcopal Hospital, Houston, in May 1968. Cooley's team was prepared to remove the heart of Clarence Nicks, a thirty-six-year-old welder who had sustained severe brain damage during a brawl the previous month. Lawyers disagreed over whether Nicks's assailant could be charged with homicide if doctors removed the respirator while his heart was still functioning.[26] Would Nicks have been killed by the barroom defendant or by the physicians who removed his heart? Moreover, since Nicks's death would constitute a homicide when he did die, an autopsy would be necessary. It was unclear to Harris County Medical Examiner Joseph Jachimczyk whether he would be able to fulfill the legal requirements of an autopsy if Nicks's heart were removed. As such, he was reluctant to let the transplant team have the heart. Jachimczyk was informed that Nicks's brain no longer functioned and that Nicks had been pronounced dead at 10:30 a.m. on May 7—he was being kept on the respirator for the purpose of keeping his heart viable. The medical examiner then promised that no charges would be brought for interfering with an autopsy if Cooley went ahead with the transplant—which Cooley did complete.[27]

Later, Dr. Norman Shumway of Stanford University also came up against the law. The family of a homicide victim wanted the victim's heart to be used for transplantation. Stanford Hospital, however, had agreed with the coroner of Santa Clara County that organs would not be taken from homicide victims.

Despite that understanding, Stanford Hospital acquired the heart and Shumway proceeded with the surgery. Lawyers for the defense argued that the defendant did not kill the victim because the victim did not die until his heart was removed. The jury agreed.[28]

The Harvard committee's preoccupation with avoiding legal conflict is underscored in a subsection titled "Legal Commentary." Members wrote: [W]e recommend the patient be declared dead before any effort is made to take him off a respirator. . . . This declaration should not be delayed until he has been taken off the respirator. . . . The reason for this . . . is that . . . it will provide a greater degree of legal protection to those involved. Otherwise, the physicians would be turning off the respirator on a person who is, under the present strict, technical application of the law, still alive."[29]

In contrast to 1957, when ethical uneasiness prompted a search for guidance from a religious source, Harvard's "Brain Death Committee" had legal concerns in mind. Since medical consensus determines legal standards of care and definitions, the acceptance of the Harvard committee redefinition of death by medical practitioners generally was an important tool in stemming the tide of legal liabilities.

Redefining death was not simply a matter of technical or professional medical concern, however. When the Harvard committee promulgated the brain-death criteria in the pages of *JAMA*, it simultaneously published a summary of "A Definition of Irreversible Coma," in the *New York Times*. Public acceptance of irreversible coma as "brain death" was crucial. If the legal ramifications surrounding brain death could be addressed by urging new customary practice, it was not so clear how public anxieties could be managed. As one Washington public health official remarked: "I have a horrible vision of ghouls hovering over an accident victim with long knives unsheathed, waiting to take out his organs as soon as he is pronounced dead."[30] The medical research community in the United States was mindful of experiences in other countries where transplantation and the redefinition of death had been debated. In May 1966, Dr. Clarence Crafoord had provoked public outcry in Sweden over the "cannibalizing" of human beings for spare parts when he suggested that persons be declared dead when flat electroencephalograms indicated irrevocable brain damage.[31] The potential for public protest was a serious concern for champions of transplantation research.

Several months after the Harvard committee announced its criteria for brain death, an article in *JAMA* noted that cardiac transplants had given the diagnosis of death "a new public dimension." The authors urged that systematic attempts be made "to assess public concern and to involve the public in a dialogue about the vital issues raised by new concepts dealing with the diagnosis of death."[32] They stressed that the public was, indeed, concerned about how death was determined. Further, they urged that "the movement toward upgrading the diagnosis of death . . . will need to be preceded by some program of public

education." If professional guidance did not mold public opinion, public interest could become problematic:

> This involvement may be misguided or even ludicrous, but it can become forceful and even restrictive.
>
> Just as styles of dissent change from period to period, so do styles of communication and the methods of molding public opinion. The form and style of the public dialogue on medical ethics has not completely taken shape, but it would appear that the dialogue will need to be candid as well as broadly based. . . .
>
> A public dialogue can and should become an important instrument in developing a climate within which medical progress and community welfare can be maximized.[33]

Organized medicine had already begun the dialogue. The AMA magazine *Today's Health* spoke to public fears over transplantation in an April 1968 article by the chief *JAMA* science writer. Heart transplantation, he explained, was unlikely to bring relief to any but a few patients—partly because of the nature of heart disease but also because of the shortage of transplantable hearts. The author reassured readers that donor hearts would not be removed prematurely. "Despite worry expressed in some quarters that the need for donor hearts might lead surgeons to remove the organ from a potential donor before he is actually dead, this is not likely to happen. Irreversible brain damage occurs within five minutes after the heart stops beating. And any surgeon would wait at least this long before starting to remove the donor heart."[34]

Efforts on the part of organized medicine could not fully shape public or medical professional opinion on transplantation and the redefinition of death, however. For example, the New York State legislature appointed a nine-member commission to hold public hearings in order to determine a "precise definition" of death for organ transplant donors. New York Supreme Court Justice J. Irwin Shaw, chairman of the Temporary Commission on Vital Organ Transplant, said that the hearings were the result of "a flurry of heart transplants."[35]

Although published discord was modest within the medical community, it is clear that at least some physicians remained unconvinced of either a legitimate need or the possession of sufficient knowledge for establishing irreversible coma as a criterion of death. The director of the National Heart Institute, Dr. Theodore Cooper, called for additional research on determining death.[36] Dr. James Hardy of the University of Mississippi dissented from even considering new criteria on the grounds that many communities were not likely to readily accept removal of a beating heart.[37] The lurid sarcasm of Dr. Edward Shaw of the University of California Medical Center, San Francisco, suggests that although dissent may have been infrequent, it was lively. The perfect solution to the donor problem, according to Shaw, would be to employ the French guillotine. Such a device would provide a donor, "in whom the precise instant at which cerebrum function ceases is beyond doubt." Moreover, there would be

no "possibility of restoration." Shaw averred that such a solution was "wholly revolting" but concluded that it was not more so than some of the suggestions he had read.[38]

Although research medicine was unable to fully contain criticism, its effort to negotiate through hostile opinion and avoid debilitating protest was not ineffective. The public remained confused, not monolithically opposed, to medical science with respect to organ transplantation and the redefinition of death. Even today, how death should be defined remains an unsettled matter of discussion and subdued debate.[39] At the historic moment of 1968, one year in an incendiary decade when challenges to professional authority were both common and shrill, even a limited embrace of controversial transplantation experimentation spelled a type of success for the backers of this research who promulgated the brain-death criteria.

When the editor of the *New York Times* penned his opinion on brain death, he either ignored or failed to see that in providing a solution to the problem of organ procurement for heart transplants, the brain-death criteria had been a response to the controversial needs of experimentation on human subjects. Noting that the Harvard committee also had organ procurement in mind, the editor interpreted their efforts chiefly as an effort to help free "the human vegetables" among us: "As old as medicine is the question of what to do about the human vegetable, the individual who—because of brain injury or disease—goes into irreversible coma while his heartbeat and metabolism continue with external aid," he observed. "Sometimes these living corpses have 'survived' for years, draining the financial and emotional resources of their families."[40]

The editor exonerated the committee's work members because, as he saw it, "Adoption of this proposal would authorize physicians in . . . tragic cases to halt the artificial respiration or other means being employed to continue 'life.'" He speculated that physicians must have been terminating treatment quietly in such cases in the past, "but always at the risk of being accused of murder." "The redefinition now suggested," he supposed, "would end that problem." The editor could not have been more wrong on at least one score: Before 1968, no physician had been accused of murder for terminating resuscitative measures.[41]

Conclusion

The Harvard committee statement begs an important question: Had physicians who discontinued resuscitative measures before 1968 killed their patients? According to the Pope, they had not. According to medical customary practice, the foundation for legal standards of care, they had not. Indeed, had the possibility of such an accusation been the only cause for concern, there would have been little reason for the profession to codify criteria for determining death at all. What had been a part of developing customary medical practice for over a decade could remain so, and with it legal standards could remain. From the point of view of organized medical research, what necessitated

action in 1968 was the possible conflict of interest caused by heart transplantation and fears over the criminalization of efforts to procure organs.

More than a medical response to a technologically-induced moral problem, "brain death" was an artifice of legal self-protection. It was designed to protect professional medicine against the possibility that the public would perceive a potential conflict of interest and become alarmed—a conflict between the profession's responsibility to care for the sick and dying and the demands of medical research to procure organs for transplant.

Notes

1. For a historical examination of death preceding 1968, see Martin S. Pernick, "Back from the Grave: Recurring Controversies over Defining and Diagnosing Death in History," in *Death: Beyond Whole-Brain Criteria*, ed. Richard M. Zaner (Boston: Kluwer, Academic Publishers, 1988), 17–74.

2. "A Definition of Irreversible Coma: Report of the Ad Hoc Committee of the Harvard Medical School to Examine the Definition of Brain Death," *JAMA* 205 (Aug. 5, 1968): 339.

3. For an account of the committee's redefinition of death that differs from the analysis here, see David J. Rothman, *Strangers at the Bedside: A History of How Law and Bioethics Transformed Medical Decision Making* (New York: Basic Books, 1991). For an account compatible with the one offered here, see Mita Giacomini, "From Death Defying to Death Defining: Technological Imperatives and the Definitions of Brain Death in 1968," M.A. thesis, History of Health Sciences, 1992, University of California at San Francisco.

4. See Giacomini for a discussion that challenges the committee's claim that financial concerns constituted one of the inducements for redefining death: "Although the Committee invoked the expense of the hospitalized comatose in its justification of the redefinition of death, there is little historical evidence to suggest those issues themselves pressed for resolution in 1968." Ibid., 40–41.

5. Lyman A. Brewer III, "Cardiac Transplantation: An Appraisal," *JAMA* 205 (Sept. 2, 1968): 101.

6. Thomas E. Starzl, "Ethical Problems in Organ Transplantation," *Annals of Internal Medicine* 67, suppl. 7 (September 1967): 33.

7. See, for example, "Surgery and Show Biz," *Newsweek*, Jan. 15, 1968, 49, and "Surgical Show Biz," *Nation*, Jan. 22, 1968, 100. See Brewer, "Cardiac Transplantation," for an example of how some members of the medical profession disapproved of the publicity.

8. "A Plea for a Transplant Moratorium," *Science News* 93 (Mar. 16, 1968): 256.

9. For an analysis that underscores the role of the EEG in redefining death, see Giacomini, "From Death Defying to Death Defining."

10. "Definition of Irreversible Coma," 87.

11. Gordon L. Snider, "Historical Perspective on Mechanical Ventilation: From Simple Life Support System to Ethical Dilemma," *American Review of Respiratory Diseases* 140 (August 1989): s2–s7; *Collier's Encyclopedia* (New York: Macmillan Educational Co., 1990), 13: 296; S. J. Somerson, "Historical Perspectives on the Development and Use of Mechanical Ventilation," *AANA Journal* 60 (February 1992): 83–84.

12. Anonymous, "A Way of Dying," *Atlantic Monthly* 199 (January 1957): 53-55.

13. John J. Farrell, "The Right of a Patient to Die," *Journal of the South Carolina Medical Association* 54 (July 1958): 231–32.

14. Pope Pius XII, "Allocution Delivered to the International Congress of Anesthesiologists," *Acta Apostolicae Sedis* 49 (Nov. 24, 1957): 1027–33; Pope Pius XII, "The Prolongation of Life," in *Ethics in Medicine: Historical Perspectives and Contemporary Concerns,* ed. Stanley Joel Reiser, Arthur J. Dyck, and William J. Curran (Cambridge, Mass.: MIT Press, 1977), 501–4.

15. As cited in "The Hopeless Case: Medical and Moral Considerations," *JAMA* 181 (Sept. 29, 1962): 1102. See also Thomas J. O'Donnell, "Artificial Resuscitation: A Moral Evaluation," *Georgetown Medical Bulletin* 14 (February 1961): 242–44.

16. William P. Williamson, "Life or Death—Whose Decision?" *JAMA* 197 (Sept. 5, 1966): 793.

17. Ibid., 795.

18. Ibid.

19. According to Ayd, "Hopeless Case," 84, an editorial in the Jan. 10, 1961, *Medical Tribune* titled "Heroic Treatment" defended the challenged position: "From time to time we are criticized for the overly dramatic and desperate treatment of moribund patients—for surrounding the poor soul with infusions, oxygen, pressor amines, residents, and attendings that the relatives can barely have a glimpse of him amid a forest of equipment. The effort is sourly criticized a 'prolongation of death,' not of life, and a plea is made for the dignity of a patient's last hours when he ought to be allowed to die in peace. . . . [However,] heroic treatment can succeed. As a result, quite a few 'moribund' patients afterward stride out of the hospital in defiance of any reasonable judgment at the time of admission."

20. He adds the following statement, remarkable in the way it reveals how the demands of scientific research can alter standards of care: "Then, in an orderly way, it can be determined whether these people already were dead but with functioning hearts and lungs, or if they had a chance of restoration of brain function. The quality of care and the discriminate application of such care to terribly damaged people was one of the great fringe benefits of transplantation." Thomas Starzl, *The Puzzle People: Memoirs of a Transplant Surgeon* (Pittsburgh: University of Pittsburgh Press, 1992), 148.

21. Ibid., 148–49.

22. D. D. Rutstein, "The Ethical Design of Human Experiments," *Daedalus* 98 (Spring 1969): 526.

23. See, for example, "Needless Transplants?" *Newsweek,* Mar. 2, 1964, 74, quoting Dr. J. Russell Elkinton, which states that while the transplant record "augues well for the clinical future; from the point of view of the clinical present [it] is less than rosy—it is black." See also, "Year of the Transplant," *Newsweek,* Feb. 10, 1964, 52, quoting a researcher as saying, "I have no words to describe my opposition—scientifically and even morally—to these transplants."

24. John H. Kennedy, "Cardiac Transplantation—A Current Appraisal," *JAMA* 203 (Mar. 4, 1968): 172–73.

25. Editorial, "What and When is Death?" *JAMA* 204 (May 6, 1968): 539–40.

26. "Death, When is Thy Sting?" *Newsweek,* Aug. 19, 1968, 54.

27. "Redefining Death," *Newsweek,* May 20, 1968, 68.

28. "Pioneering Heart Transplant Surgeon Retires," *Stanford Daily,* Jan. 25, 1993, 1. Dr. David Hume also was charged with murder. See Starzl, *Puzzle People,* 148. Redefining death in 1968 was not, in itself, sufficient to stave off legal liability. Shumway's experience was instrumental in the California legislature's adoption of a redefinition of death statute in the early 1970s. See also Tucker v. Lower, no. 2831 (Richmond Law & Eq. Ct. May 23, 1972).

29. "Definition of Irreversible Coma," 88.

30. "When Are You Really Dead?" *Newsweek,* Dec. 18, 1967, 87.

31. "What Is Life? When Is Death?" *Time,* May 27, 1966, 78.

32. John D. Arnold, Thomas F. Zimmerman, and Daniel C. Martin, "Public Attitudes and the Diagnosis of Death," *JAMA* 206 (Nov. 25, 1968): 1953.

33. Ibid., 1954.

34. Ulys H. Yates, "Transplantation: Today and Tomorrow," *Today's Health,* April 1968, 37.

35. "State Seeking to Define Transplant Donor Death," *New York Times,* Nov. 28, 1968, 48.

36. "Symposium Hears Transplant Plea," *New York Times,* Sept. 9, 1968, 23.

37. Ibid.

38. "Donors for Organ Transplants—Letter to the Editor," *JAMA* 207 (Mar. 31, 1969): 2439.

39. See, for example, Linda L. Emanuel, "Reexamining Death: The Asymptomatic Model and a Bounded Zone Definition," *Hastings Center Report* 25, no. 4 (July-August 1995): 27–35; Alexander Morgan Capron, "Legal Issues in Pronouncing Death," *Encyclopedia of Bioethics,* ed. Warren T. Reich, 5 vols. (New York: Macmillan Library Reference, 1984), 534–40; Robert M. Veatch, *Death, Dying, and The Biological Revolution: Our Last Quest for Responsibility,* rev. ed. (New Haven: Yale University Press, 1989). As an example of current popular understanding of how definitions of death are considered, see Jim Holt, "Sunny Side Up," *New Republic,* Feb. 21, 1994, 23.

40. "Redefining Death," *New York Times,* Aug. 8, 1969, 32.

41. Ad Hoc Committee of the American Electroencephalographic Society, "Report of the Ad Hoc Committee . . . Society on EEG Criteria for Determining Cerebral Death and the Electroencephalogram," *JAMA* 209 (Sept. 8, 1969): 1505–59.

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Correction

The title page used as on illustration on page 77 of "Therapeutic Method in the Later Middle Ages: Arnau de Vilanova on Medical Contingency" by Michael R. McVaugh and Luis García Ballester (Autumn 1995 issue) was incorrectly attributed. As Professor McVaugh writes: "When Arnau de Vilanova's *Regimen Sanitatis* for King Jaume I of Aragon was published in Louvain in the early 1480s, an anonymous commentary on the *Regimen Sanitatis Salernitanum* was included in the same volume. By the second half of the decade, printers had decided that the commentary must also have been written by Arnau, and the attribution stuck down to the twentieth century. But in the last fifty years scholars like Rene Verrier and Juan Antonio Paniagua have used stylistic considerations and internal references within the commentary to establish that it was written in the north of Europe by a writer from Brabant, and may indeed have been composed specifically for the Louvain edition." The editors regret the error and thank the authors for bringing it to their attention.

Picture Credits

Page 142: Walter Truslow, "Treatment of Structural Scoliosis," *American Journal of Orthopedic Surgery* 8 (November 1910): 276.

Pages 144, 158: United States Patent and Trademark Office, Washington, D.C.

Page 150: "Correction in Lateral Curvature," *Transactions of the American Orthopedic Association* 12 (1899): 33.

Page 151: E. G. Abbott, "The Mechanics of a Plaster-of-Paris Cast in Fixed Lateral Curvature of the Spine," *Journal of the American Medical Association* 63 (Dec. 12, 1914): 2122.

Page 152: *Detroit Pharmacal Company Physicians Supplies . . . 1894*, 292.

Page 154: "Injury to the Spine: Invention and Application of Paper Jacket," *Medical News* 60 (Jan. 16, 1892): 57; "The Plaster of Paris, Wood, Aluminum, and Other Spinal Supports," *New York Medical Journal* 64 (Mar. 30, 1895): 388.

Page 155: "A Case of Scoliosis Relieved by Operation on the Transverse Process of One of the Vertebra," *American Journal of Orthopedic Surgery* 8 (1910–1911): 304.

Page 156: 1903 pharmaceutical catalog of F. W. Braun & Company, 312.

Page 157: *Delineator* 49 (May 1897): vi, reprinted with permission of the Butterick Company Archives, New York.

Page 164: Historical Division, Cleveland Medical Library Association.

Pages 168, 169, 170, 172, 173, 176, 178, 179: Karl Bürker, "Zählung und Differenzierung der körperlichen Elemente des Blutes," in *Handbuch der physiologischen Methodik*, ed. Robert Tigerstedt, vol. 2 (Leipzig: S. Hirzel, 1913), 13 (Figs. 3 and 4), 15 (Fig. 5), 22 (Fig. 9), 53 (Fig. 11), 21 (Fig. 18), 127 (Fig. 19), 123 (Fig. 20), 125 (Fig. 21), 109 (Fig. 22).

Pages 170, 171, 176: Rudolf R. von Limbeck, *The Clinical Pathology of the Blood*, trans. Arthur Latham and John Nachbar (London: New Sydenham Society, 1901), 12 (Fig. 6), 13 (Fig. 7), 16 (Fig. 8 cross-section), 12 (Fig. 16), 13 (Fig. 17).Page 171: Fig. 8 counting chamber from M. L. Verso, "The Evolution of Blood-Counting Techniques," *Medical History* 8 (April 1964): opp. 150.

Page 172: Fig. 10, James Campbell Todd, *Clinical Diagnosis*, 2d ed. (Philadelphia: W. B. Saunders Company, 1912), 194.

Page 173: Fig. 12, W. Brünings, "Ein neuer Apparat für Blutkörperchen zählung," *Archiv für die Gesammte Physiologie des Menschen und der Thiere* 93 (January 1903): 402.

Page 174: Fig. 13, Karl Bürker, "Eine neue Form der Zählkammer," *Archiv für die Gesammte Physiologie des Menschen und der Thiere* 107 (April 1905): 429; Fig. 14, Bürker, "Erfahrungen mit der neuen Zählkammer nebst einer weiteren Verbesserung derselben," *Archiv für die Gesammte Physiologie des Menschen und der Thiere* 118 (June 1907): 462.

Page 176: Fig. 15, Louis-Charles Malassez, "Sur les Perfectionnements les plus Récents Apportés aux Méthodes et aux Appareils de Numération des Globules Sanguins," *Archives de Physiologie Normale et Pathologique Deuxième Série* 7 (1880): 386.

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Pascal James Imperato, "Introduction" and "Smallpox and Measles in Mali: Contrasting Control Strategies and Outcomes"; *John S. Marr and Curtis D. Malloy,* "An Epidemiologic Analysis of the Ten Plagues of Egypt"; *Mahfouz H. Zaki and Mary E. Hibberd,* "The Tuberculosis Story: From Koch to the Internet."

Forthcoming Issues—

Howard S. Barrows, Guest Editor, "Medical Education for the Future"

Eric Curtis, Guest Editor, "History of Dentistry"

Phillip V. Davis, Guest Editor, "Organ Donation and Public Policy"

Jonathon Erlen, Guest Editor, "Drug Policy in the United States"

Alan Hawk, Guest Editor, "Medical Spoils of War"

William G. Rothstein, Guest Editor, "When Did a Random Patient Benefit from a Random Physician?"

Renate Wilson, Guest Editor, "Eighteenth-Century Traffic in Medicines and Medical Ideas"

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The Editor also welcomes unsolicited manuscripts. Information on style is given on the inside back cover of this issue.